DETAILED ENERGY AUDIT OF MAURYA SHERATON HOTEL AND TOWERS

FINAL REPORT SUBMITTED TO

MAURYA SHERATON HOTEL AND TOWERS

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We gratefully acknowledge the co-operation of Mr. Muralidharan Menon, Chief Engineer and Mr. H.C.Vinayaka, Deputy Chief Engineer of Maurya Sheraton Hotel and Towers and their hospitality during the energy audit.

We wish to thank Mr.Vinay Vasudev, Mr. Shiv Kumar Nair, Mr. Kiran and Mr. Mahender of engineering and maintenance division of Maurya Sheraton Hotel and Towers for supplying useful data and assistance during field measurements.

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Executive Summary

At the instance of the Welcome Group, a detailed energy audit study was carried out at Welcome Group Maurya Sheraton Hotel & Towers, New Delhi by Tata Energy Research Institute (TERI), New Delhi.

Welcome Group Maurya Sheraton Hotel & Towers is a 430 bed Five star deluxe luxury hotel, with rooms ranging from single/double occupancy Indian or European style ones to lavish suites. Other facilities like restaurants, bars, conference rooms, banquet halls, executive club rooms, health club & swimming pools etc have also been provided.

The main aim of the energy audit was to make a detailed study of the building envelope and energy systems, identify potential areas of energy conservation and recommend energy saving measures along with cost benefit analysis of the same.

The energy audit study carried out at Welcome Group Maurya Sheraton Hotel & Towers can be broadly categorised under lighting audit, HVAC system audit, electrical system audit and audit of steam/hot water system. The executive summary highlights the major findings and recommendations of the energy audit.

Connected Load

The total connected load at the hotel & towers is approximately 3378 kW.

Areawise, the maximum load is installed in service area, (54.71%), followed by public area (31.3%). The guest area contributes 13.3% and the external areas account for remaining 0.10%.

Systemwise, HVAC (52.3%) and lighting (20.3%) are the two major load centers remaining 27.4% load is of equipment.

Consumption Pattern

The average total annual energy consumption is approximately 25.4 million kWh. The electricity accounts for 47.3% (12 million kWh), LDO for 39.4% (933 KL), HSD for 7.5% (187 KL) and LPG shares the remaining 5.8% (178×10^3 kg) of the total energy consumption.

The energy consumption is maximum during the summer months of July and August and minimum during the winter months of January and February.

Various energy conservation options used by the hotel engineering and maintenance staff has brought down the energy consumption by 14%in last six years.

Energy Cost

The total money paid by the hotel to buy different kinds of energy used in hotel amounts to approximately Rs 58.5 millions per year. Electricity accounts for 84.3% of the total energy cost followed by LDO (11%), HSD (25%) and LPG (2.3%).

Energy cost has increased by 125% over the past six years mainly due to increase in energy price rather than due to increase in energy consumption. This clearly highlights the importance of energy conservation in years to come.

Building envelope

The Maurya Sheraton Hotel & Towers (MSHT) comprised of two separate building blocks - the Hotel and the Towers. The Hotel is a X - shaped building with 6 guest floors in addition to ground floor and basement floor. The basement and ground floor mainly houses service and public areas. The building is stone clad with double-glazed bay windows. The upper storeys have stepped terraces which are landscaped. The tower block is compact in shape and has 8 guest floors in addition to basement and ground floor and topmost floor houses restaurants and conference room. The tower block is also stone clad and has double-glazed bay windows.

Lighting System

The total installed load at MSHT is estimated to be 685 kW which is approximately 20.3% of the total connected load of the hotel.

The average power density (installed lighting load per unit floor area of the hotel) is around 14.9 W/m^2.

The total average annual electricity consumption in lighting is approximately 2.4 million kWh which is 22.3% of the total electricity consumption.

The average lighting level (lux level) in many areas is below the recommended value. The existing lighting schemes have been designed based more on aesthetics and psychological factors than the energy efficiency. That is why even with the best operating controls consumption is significant.

The main lamp types used are incandescent and miniature halogens in guest and public areas, and fluorescent lamps in service areas.

The major energy saving options consist of replacement of incandescent lamps with energy efficient compact fluorescent lamps, replacement of magnetic ballasts and integration of lighting control systems.

At present electricity tariff, the annual saving in lighting consumption is estimated to be Rs 32 lakhs against an initial investment of Rs 26 lakhs with an approximate pay back period of 9 months.

HVAC System

The total installed capacity of the air conditioning plant at MSHT is over 1200 TR and the total connected load of air conditioning system is approximately 1581 kW which is 46.8% of the total connected load.

Based on the analysis of the HVAC load it has been estimated that total electricity consumption in HVAC system is approximately 4.8 million kWh which is 39.8% of the total electricity consumption in the hotel. Within the HVAC system maximum electricity is consumed by the compressors (42.3%), CT fans & pumps consume 34.1% and the AHUs and FCUs share 13.5% and 8.7% of the total HVAC consumption respectively.

At full load (100% vane opening), the average operating chiller efficiency is found to be 0.738 kW/TR as against the rated chiller efficiency of 0.708 kW/TR, an increase of just 4% which is not very significant.

It has been also observed that the chillers operated at maximum efficiency when they are loaded in the range of 70 -80% range of their maximum capacity.

Based on the measurement taken on ten sample Air Handling Units, it was found that AHUs of AH - 6 model were delivering about 11.4 TR, AH -7 about 18.1 TR, AH - 9 about 216 TR and AH - 11 about 13.9 TR as against the rated capacity of 16 TR, 30 TR & 45 TR respectively.

Fan CFM of AH - 7, AH - 9, AH -11 type AHUs were found to be on lower side except in AH -6 type where it was on higher side. But the difference was not very significant except in pavilion AHU which was observed operating at low efficiency.

Wet bulb approach of cooling towers were measured in the range of 2 - 7°F which is quite adequate. The cooling towers were found to be operating at 45 - 80% efficiency range as against the design efficiency of 52%. It was also observed that the voltas tower was operating at a higher efficiency as compared to the Paharpur cooling tower.

The estimated flow in chilled water line and condenser water line are more than the required flow.

Inspite of the HVAC equipment maintained well and with the microprocessor control, and are operated at a high efficiency, the TERI audit team has found two energy conservation options for significant saving which are as follows:

1. With the help of monthly building load profile and chiller efficiency curve a schedule can be developed to optimise the chiller bank operation. It has been estimated that it would yield an annual saving of Rs 4.5 lakhs without any investment.

2. With the help of pump characteristics curves and measurement taken on chilled water pumps and condenser water pumps, it has been observed that they are

operated to maintain a flow which is much more than the required flow. It has also been observed that with one smaller size impeller of the same pumps the flows can be corrected and this would also save energy. If it is assumed that three chilled water pumps and three condenser water pump are running round the clock, it has been calculated that an annual saving of Rs 15.7 lakhs can be achieved.

Electrical Systems

Power Factor

The hotel draws power supply through five distribution transformers of 1000 KVA, 11/0.433 KV rating each. The power factor of each transformer varies depending upon the load on transformers.

Capacitor banks with automatic power factor correction relays have already been installed on three out of five transformers to improve the overall power factor of the hotel.

A total of 530 KVAR has been installed to improve the power factor for a total connected load of 4555 KVA.

Various data on power factor was collected from the log books. The data was collected for the months of August 94 and January 95. These two months were particularly selected so as to study the daily variation of power factor when automatic power factor correction relays were functioning and when they were out of order.

A large variation of power factor values have been observed when the capacitor banks were switched on/off manually. It is, therefore, recommended to rectify the automatic power factor correction relays installed in the sub-station for better control of power factor.

No capacitor banks have been installed on transformer no. 2 & 5. Power factor of transformer no 2 is good because it feeds power mainly to resistive loads of the hotel. Power factor of transformer no. 5 varies from 0.5 to 0.94 depending upon the load on the transformer. It is recommended that the power factor of transformer-5 be maintained at about 0.95 at all loads. Although such improvement would not reflect in electricity bill, it will improve the quality of power and release a part of system load for additional loads/future expansion.

It was worked out that a total of 70 KVAR should be installed on the transformer-5 with automatic power factor correction relay. And an investment of Rs. 36,000 would be required to improve the power factor of transformer-5 to 0.95.

Electric motors

In order to evaluate the performance of motors and to see how they are loaded, load tests were conducted on all the available motors equal to and above 18.5 kW (25 H.P.) rating.

A total of five motors out of 12 tested were found to be oversized for their respective application.

All five oversized motors are recommended to be replaced by proper sized standard motors. Economics of such replacements show that by investing a total sum of Rs. 55,000 in such replacements, an annual saving amounting to Rs. 41,000 could be achieved.

A case study illustrating the procedures and calculations involved to work out potential savings by replacing oversized motor with appropriate motor has been included in the report.

Economic viability of use of energy efficient motors were also checked for all the oversized motors. Since these motors have already been recommended to be replaced with properly sized standard motors, this option presents a second alternative. An investment of Rs 88,500 would be required in replacement cases of five oversized motors by properly sized energy efficient motors. The measure would result in a saving of Rs.95,000 per annum.

Boilers

Three HSD fired boilers of capacities; 5 tph, 4 tph, and 2.5 tph have been installed to meet the steam and hot water requirement at Maurya Sheraton Hotel & Towers. The boilers operate at a design pressure of 8 kg/cm^2 and during audit it has been observed that most of the time the 5 tph boiler is kept in operation.

The analysis carried out shows that the boiler-1 operates at a thermal efficiency of 80.9%.

The excess air level in boiler - 1 was computed to be 69% against an optimum valve of 40%. By reducing the excess air level to the recommended optimum level the boiler efficiency can be increase to about 82.4% and this would yield a fuel saving of 13.2 KL or Rs 90 000 annually.

Steam Network

The steam network system covers (a) steam demand (b) steam utilisation (c) steam supply and distribution (d) condensate recovery and (e) flash steam recovery. The steam is utilised in (i) laundry (ii) main kitchen (iii) health club and (iv) absorption chillers.

In the laundry section, bulk of the heat supplied to dryer escapes through the exhaust gases. However, the economic viability of waste heat recovery systems such as heat wheel/heat pipe does not favour the use of such as systems.

The laundry section has steam heated press (total 10 in number) whose non-working surfaces are not insulated. The typical heat losses from these bare surfaces is 250-480 Btu/ft^2 - hr resulting in a steam loss of 2000 kg annually. By insulating bare surfaces with glass wool the surface losses can be minimised.

In the steam distribution side, the insulation in the lines and flanges were damaged or missing totally. It is recommended to replace the damaged/missing insulation.

Summary of Recommendations

S.No.	Major Energy Conserving Options	*Annual Savings (Rs)*	*Investment*	*Payback (years)*
Lighting Systems				
1	Replacement 100W gls lamps by 20W PLE/T lamps in guest rooms (4hrs/room) No of rooms - 430. (Occupancy considered - 80%)	Rs 16,20,115	Rs 12 04 000	8 months
2(a)	Regulated dimmers linked to occupancy sensors for guest corridors.	Rs 2 43 684		
	or			
2(b)	Replacement of 40 W gls by 15W PL E/T lamp in guest corridors.	Rs 5 49 229	Rs 4 42 000	9 months
3	Replacement of 40 W fluorescent tubelights by 36W Trulite	Rs 2 55 600	Excess in investment Rs.2,01,257	9½ months
4	Replacement of conventional magnetic ballast by electronic ballast in twin fixtures.	Rs 4 13 023	Rs 4 68750	
5	Dimming of lights during preparation/cleaning of Dumpukht & Bukhara.	Rs 27 239	None	
6	Replacement of 40W gls by 15W PLE/T in Pavilion	Rs 49 241	Rs 35 750	9 months
7	Replacement of 40W milky gls lamps by 15 W PLE/T in Maurya I lobby	Rs 2 10 393	Rs 1 52 750	9 months
8	Replacement of 40 W milky gls lamps by 15 W PLE/T Maurya II lobby	Rs 1 13 884	Rs 91 650	9 months
Boiler				
9	Optimisation of excess air level in boiler-1 so as to improve boiler efficiency by 1.5%	Rs 90 000	-	-
Electrical Systems				
10	Improving power factor of transformer no 5 to 0 95	-	Rs 36 000	-
11	Replacement of oversized motors with appropriate sized one	Rs 41 000	Rs 55 000	1.35 yrs
12	Replacement of oversized motors with appropriate sized energy efficient motors	Rs 95 000	Rs 88 500	11 months
HVAC Systems				
13	Optimisation of Chiller bank operation	Rs 4 50 000	-	-
14	Replacement of existing with one size smaller impeller in chilled water pumps and condenser water pumps	Rs 15 70 000	Rs 1 00 000	< 1 month

CHAPTER 1

Energy Analysis

The Tata Energy Research Institute has conducted an energy audit at the Maurya Sheraton Hotel and Towers, New Delhi. Measurement of energy and recording the consumption of energy is very important since analysis is to be done based on this recorded information and future course of action will be based on the analysis carried out. The energy data was available for 6 consecutive years starting from 1989–90 to 1994–95.

The total connected load at the hotel and towers is 3378 kW of which service area accounts for 54.70%, public area for 31.3%, guest area for 13.3% and external areas account for remaining 0.70% of the connected load (Figure 1.1). However, the consumption break-up shows that service area accounts for 70.7%, public area for 17.6%, guest area for 11.6% and the external areas account for remaining 0.10% of the total consumption(Figure 1.2). However sourcewise break–up shows that electricity accounts for 47.3%, LDO for 39.36%, HSD for 7.45% and LPG accounts for remaining 5.83% of the total consumption (Figure 1.3). The systemwise break up of connected load shows that HVAC accounts for 52.30%, power for 27.4% and lighting for 20.3% of the total load (Figure 1.4).

The monthly variation of total energy consumption for 6 years (Figure 1.5) and its average shows that maximum energy consumption takes place in the month of July and the lowest consumption takes place in the months of January and February. The energy consumption in the month of July averages to about 24,83,953 kWh and those in the months of January and February are 18,16,808 kWh and 18,11,503 kWh respectively. Source-wise energy consumption profiles for six years and its average have also been developed. The average electricity consumption profile (Figure 1.6) shows that the peak consumption is reached in the month of August to about 1228575 kWh and the minimum consumption is in the month of January which is about 785108 kWh. The average HSD consumption profile (Figure 1.7) shows that the maximum consumption is reached in the month of July which is about 32186 litres and the minimum in the month of April which is about 5871 litres. The average LDO consumption (Figure 1.8) profile does not have sharp monthly variations, the minimum being 72125 litres in the month of September and the maximum in the month of December, the consumption being 83920 litres. The maximum average LPG consumption (Figure 1.9) is in the month of December which is about 10413 kg and the minimum average is in the month of April which is 9305 kg.

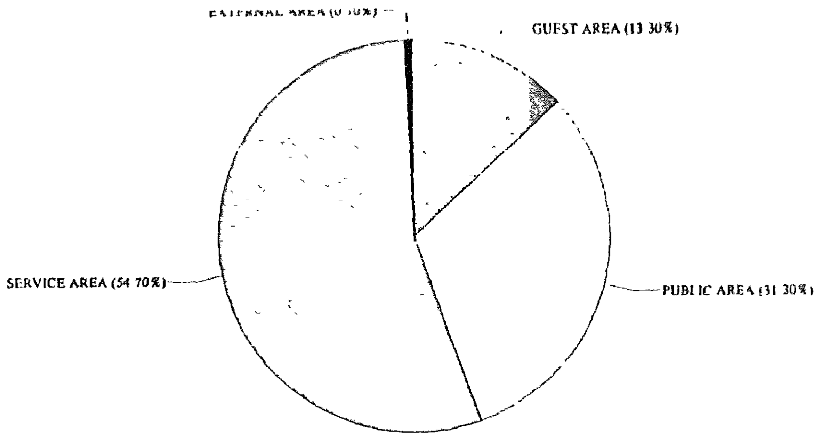
Trends in increase in energy costs and its effect on the overall energy costs of the hotel have also been developed. The figures and graphs show that energy expenditure have increased 125% over 6 years from 1989–90 by (Rs 26 million) to 1994–95 (Rs 58.5 million) (Figure 1.10 & 1.11) though the total energy consumption has been reduced by 14% over 6 years, due to practice of energy conservation measures. The total energy consumption is 1989-90 was 28 million kWh which has gone down to 24 million kWh in 1994–95 (Figure 1.12). Sourcewise breakup of energy costs (Figure 1.13) show that on an average electricity consumption accounts for 84.28%, LDO for 11.03%, HSD for 2.46% and LPG 2.23% of the total energy costs. Monthly variation in energy costs have also been developed (Figure 1.4).

Energy indices have been developed as total energy cost/quantity per occupied room per day. Sourcewise energy indices have also been developed i.e. electricity consumption in kWh/occupied room day, HSD consumption in liters/occupied room day, LDO consumption in liters/occupied room day and LPG consumption in kg/occupied room day.The average electricity consumption index (Figure 1.15) shows that the average consumption per occupied room per day reaches to a maximum of about 111 kWh in August and a minimum of 71kWh in January.The average HSD consumption index (Figure 1.16) shows that peak consumption is reached in June to about 3 liters per occupied room per day and the minimum consumption is in January which is about 0.55 liters per occupied room per day.The average LDO consumption index (Figure 1.17) has a more or less a linear profile varying between 7.8 liters/occupied room per day in April to about 6.8 liters/occupied room per day in September. The LPG consumption index (Figure 1.18) shows a maximum of 0.95 Kg/occupied room per day in December and a minimum of 0.87 Kg occupied room day in May.

The energy cost/occupied room per day has risen from Rs 190 in 1989–90 to Rs 450 in 1994–95, and about 85% of this cost is accounted for by electricity (Figure 1.19).

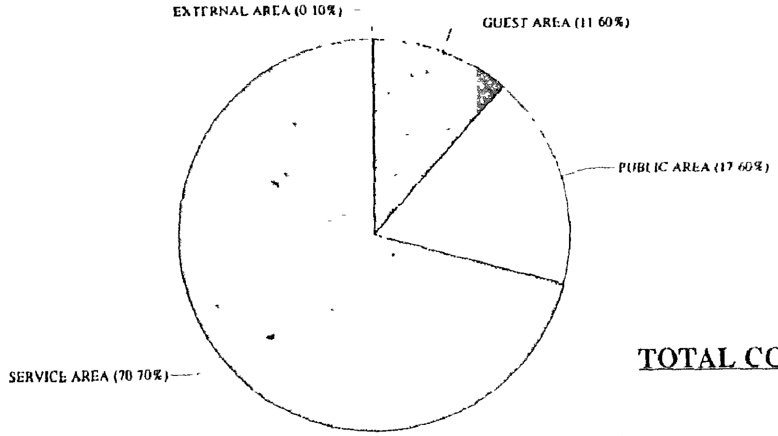
Sourcewise energy indices have also been developed per unit area per month of the hotel and towers. The electricity consumption per unit area (Figure 1.20) is maximum in August i.e., 28kWh per sq m and minimum in January i.e., 17kWh per sq.m. The HSD consumption per sq.m. (Figure 1.21) is 0.63 liters in July and 0.1 liters in February. The LDO consumption (Figure 1.22) is 1.8 liters/sq m per month in December and 1.56 liters/sq m per month in September.

AREA WISE LOAD BREAKUP



CONSUMPTION BREAK UP

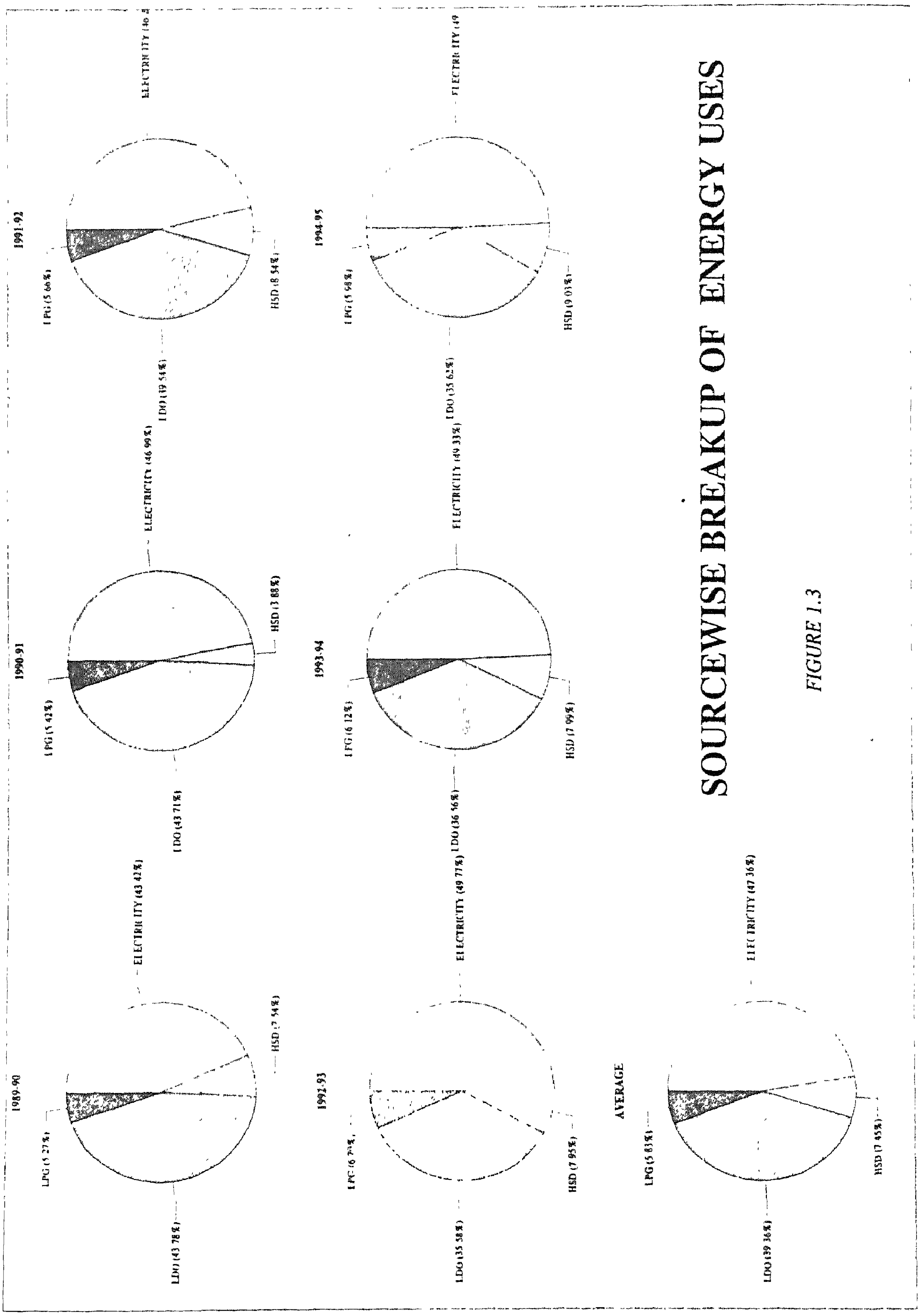
FIGURE 1.1



TOTAL CONNECTED LOAD 3378 kW

CONNECTED LOAD BREAK UP

FIGURE 1.2



SOURCEWISE BREAKUP OF ENERGY USES

FIGURE 1.3

SYSTEM WISE CONNECTED LOAD BREAK UP

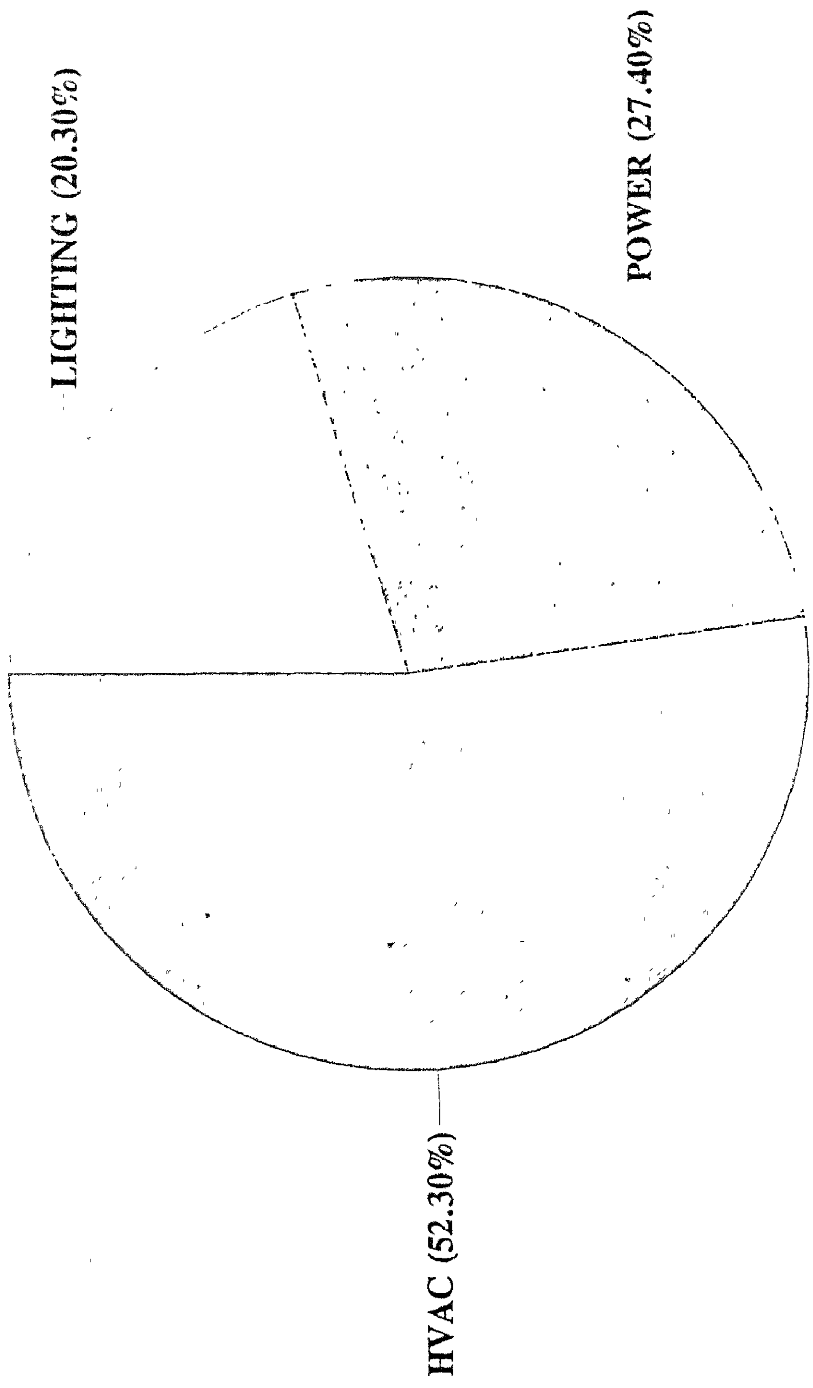


FIGURE 1.4

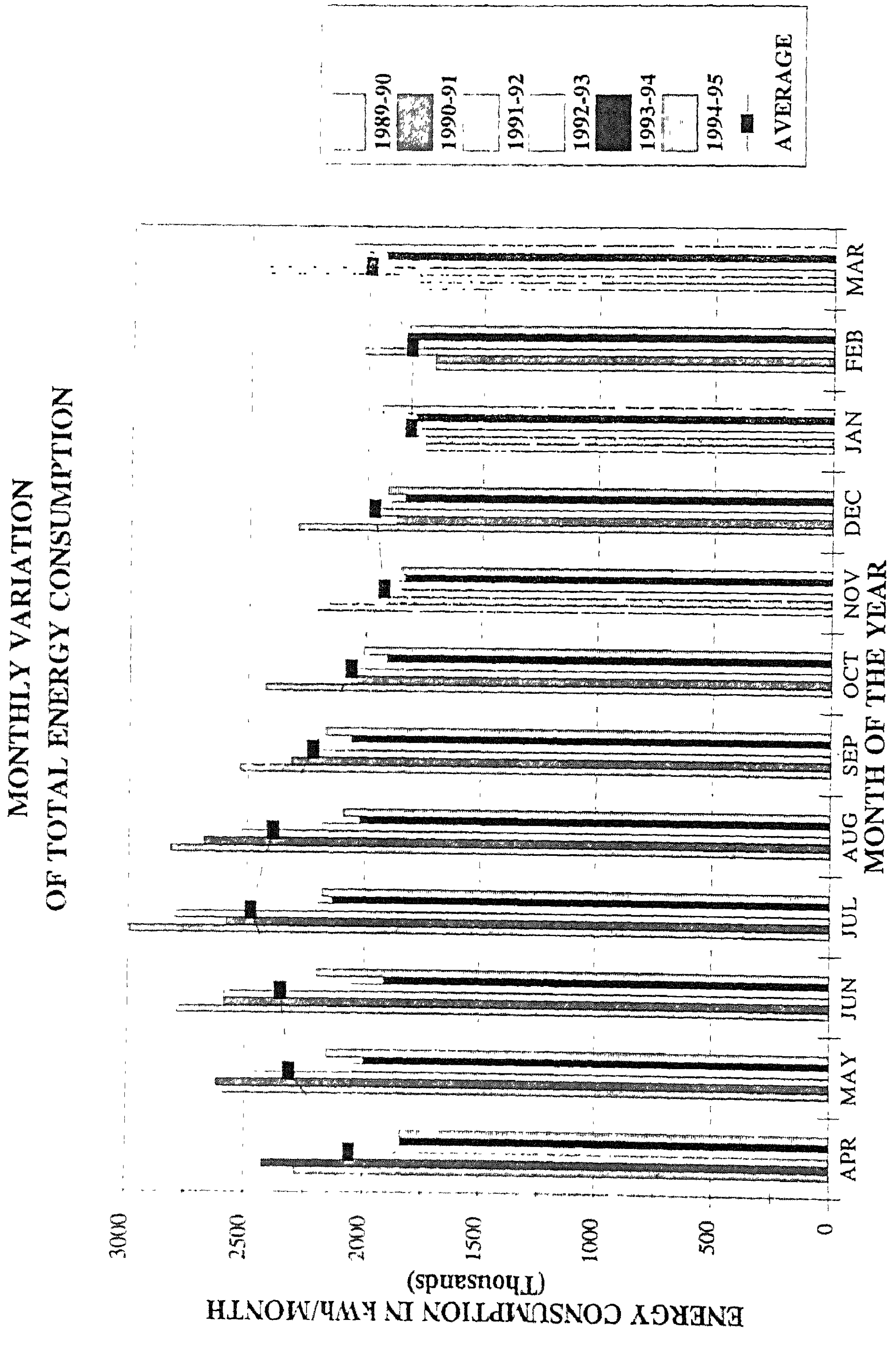

MONTHLY VARIATION
OF TOTAL ENERGY CONSUMPTION
ENERGY CONSUMPTION IN kWh/MONTH
(Thousands)
3000
2500
2000
1500
1000
500
0
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
JAN
FEB
MAR
MONTH OF THE YEAR
1989-90
1990-91
1991-92
1992-93
1993-94
1994-95
AVERAGE

FIGURE 1.5

SOURCE WISE ENERGY CONSUMPTION

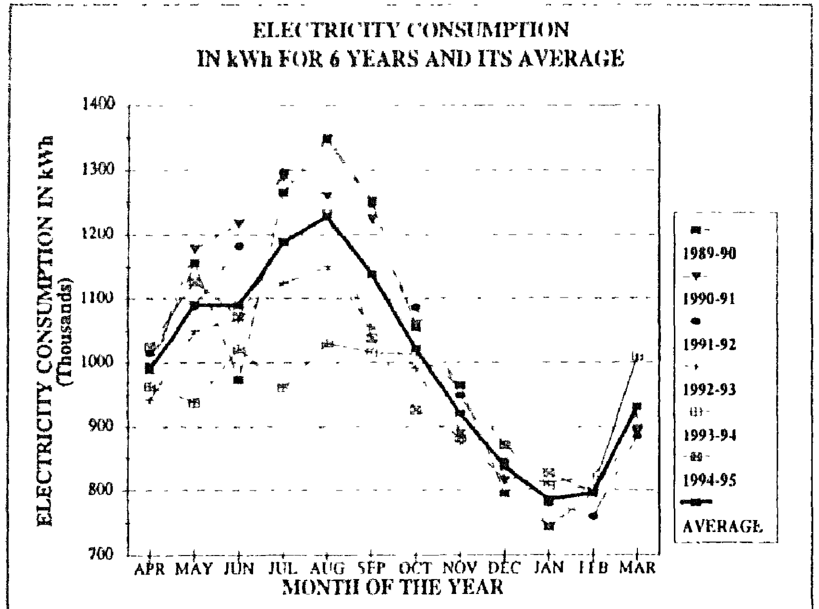

ELECTRICITY CONSUMPTION IN kWh FOR 6 YEARS AND ITS AVERAGE

FIGURE 1 6

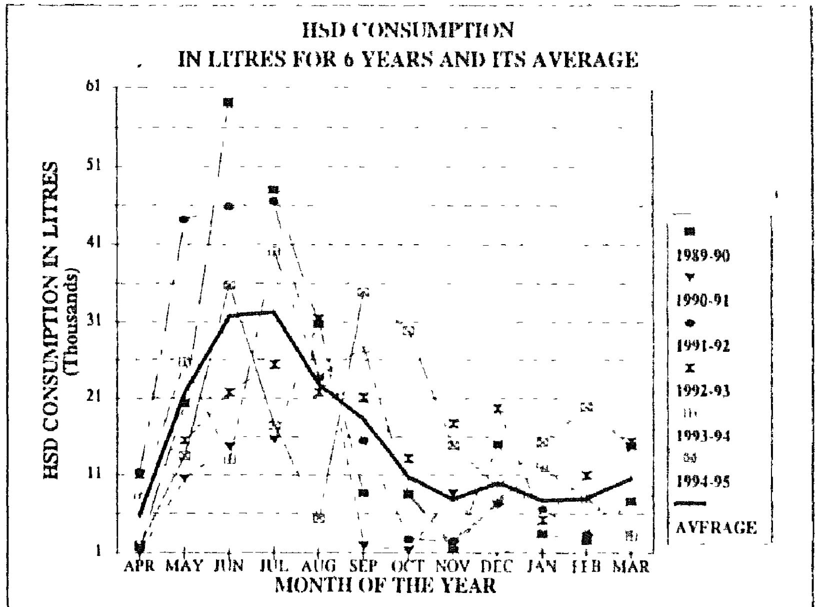

HSD CONSUMPTION IN LITRES FOR 6 YEARS AND ITS AVERAGE

FIGURE 1 7

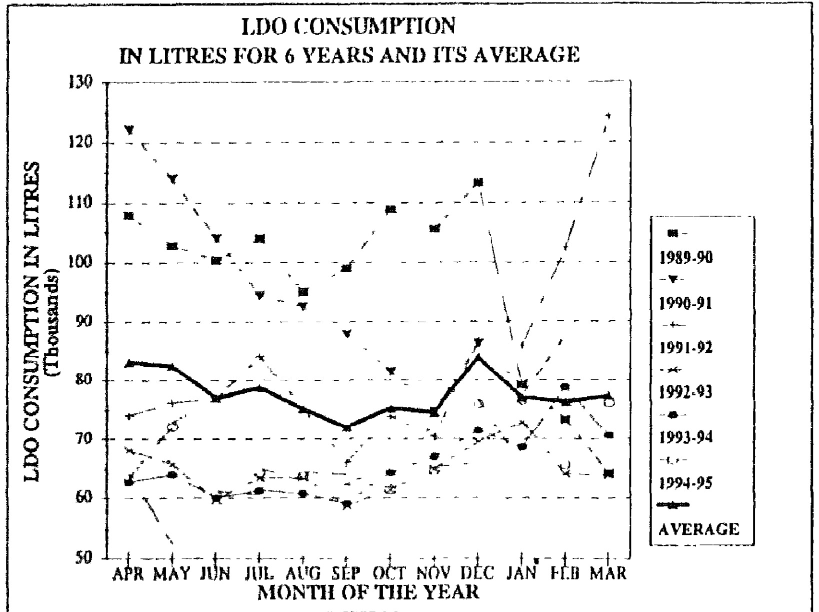

LDO CONSUMPTION IN LITRES FOR 6 YEARS AND ITS AVERAGE

FIGURE 1 8

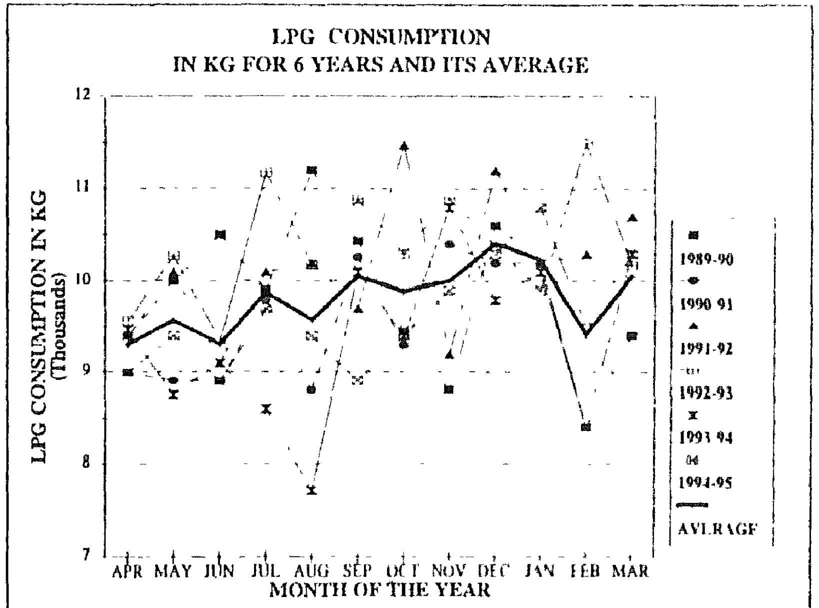

LPG CONSUMPTION IN KG FOR 6 YEARS AND ITS AVERAGE

FIGURE 1 9

ENERGY COSTS

ENERGY COSTS
FOR 6 CONSECUTIVE YEARS

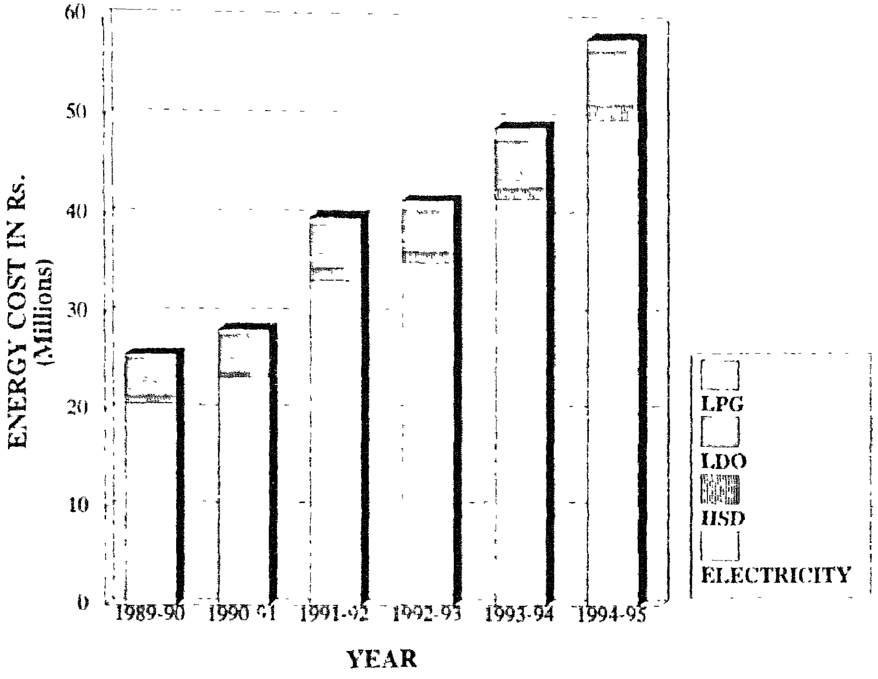


FIGURE 10

RISE IN TOTAL ENERGY COST
WITH 1989-90 AS BASE YEAR

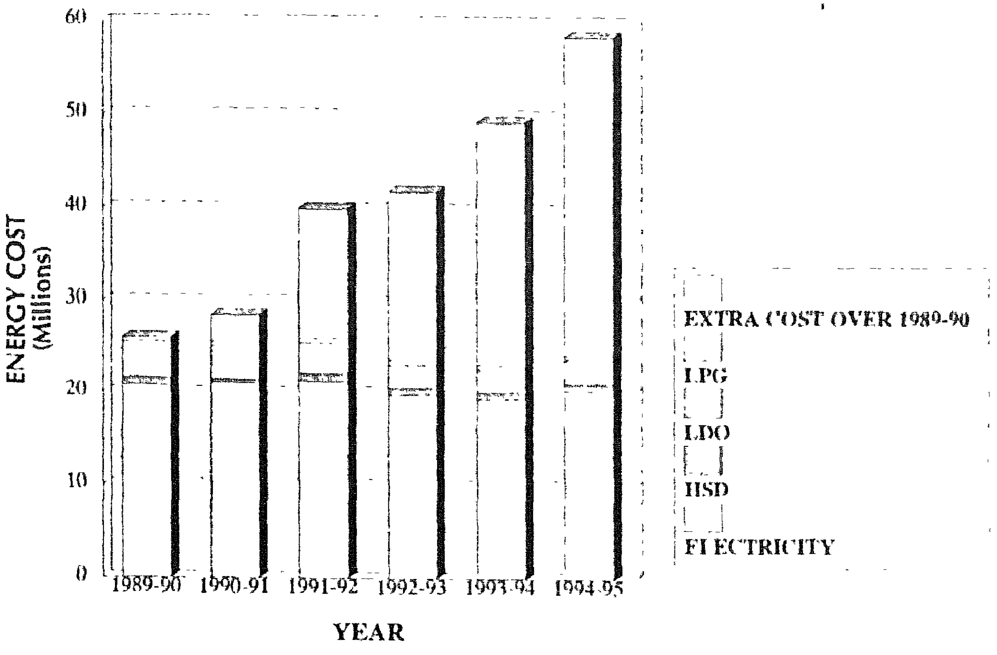


FIGURE 11

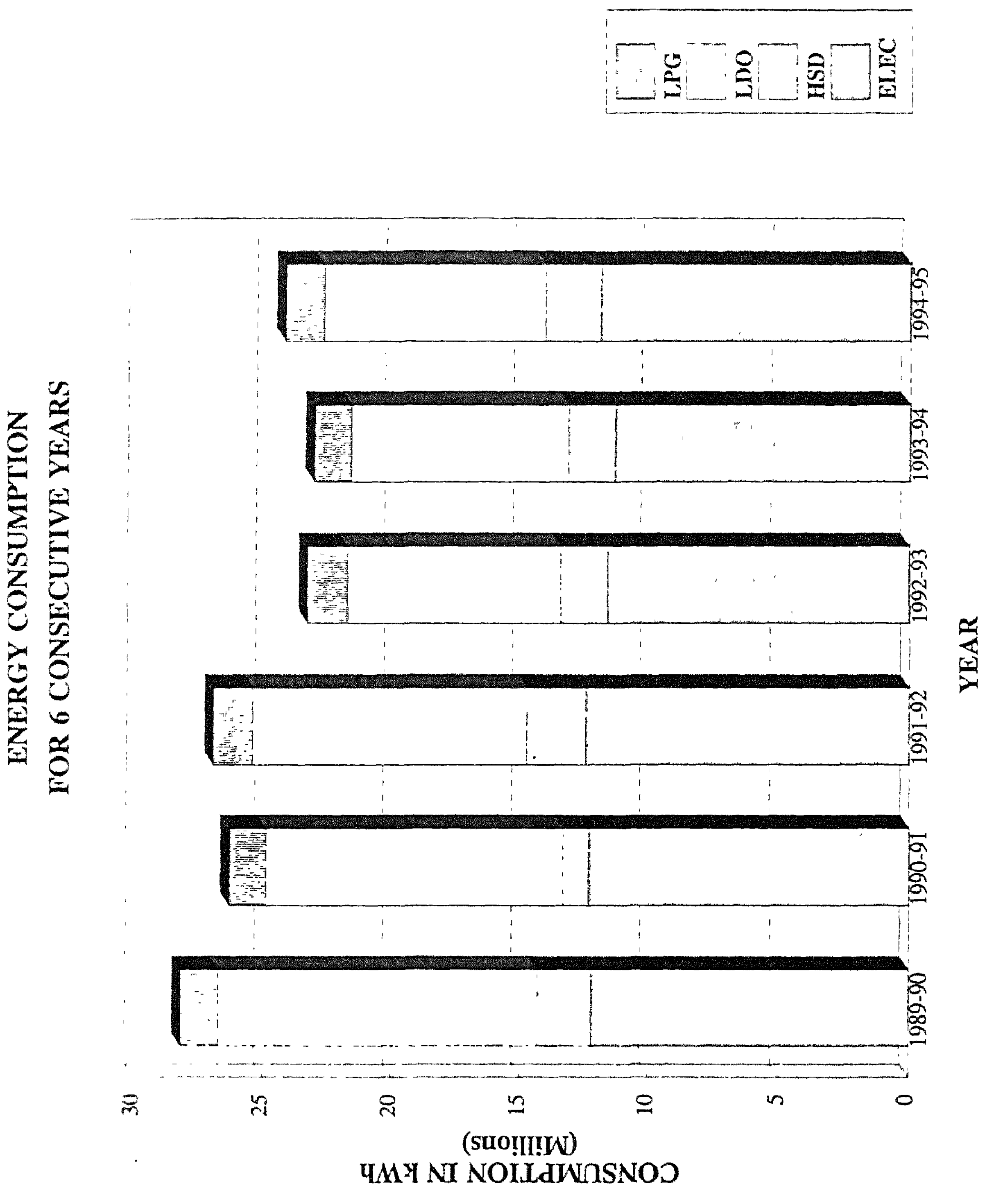
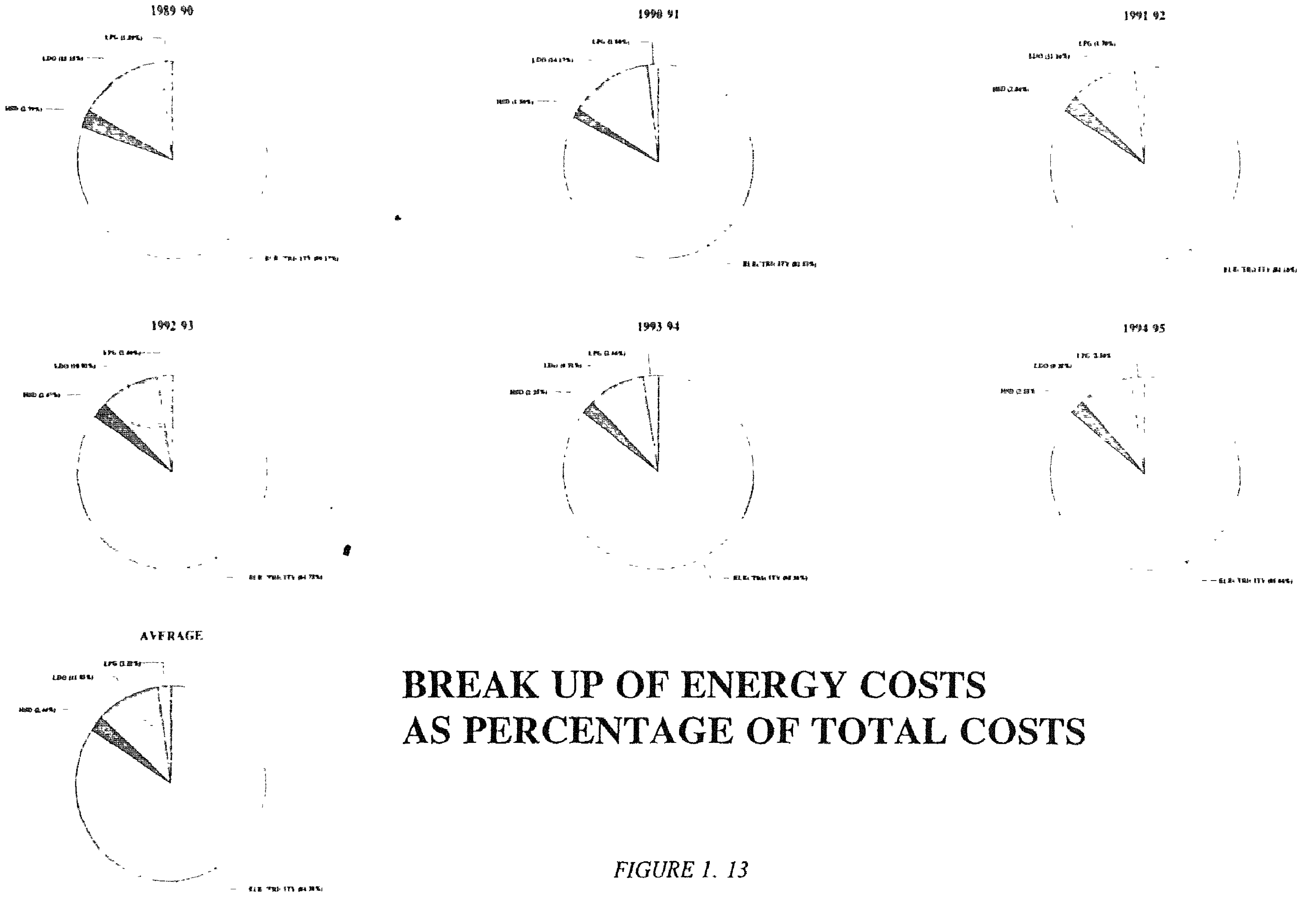

ENERGY CONSUMPTION
FOR 6 CONSECUTIVE YEARS
CONSUMPTION IN KWh
(Millions)
30
25
20
15
10
5
0
1989-90
1990-91
1991-92
1992-93
1993-94
1994-95
YEAR
LPG
LDO
HSD
ELEC

FIGURE 1. 12



BREAK UP OF ENERGY COSTS
AS PERCENTAGE OF TOTAL COSTS

FIGURE 1. 13

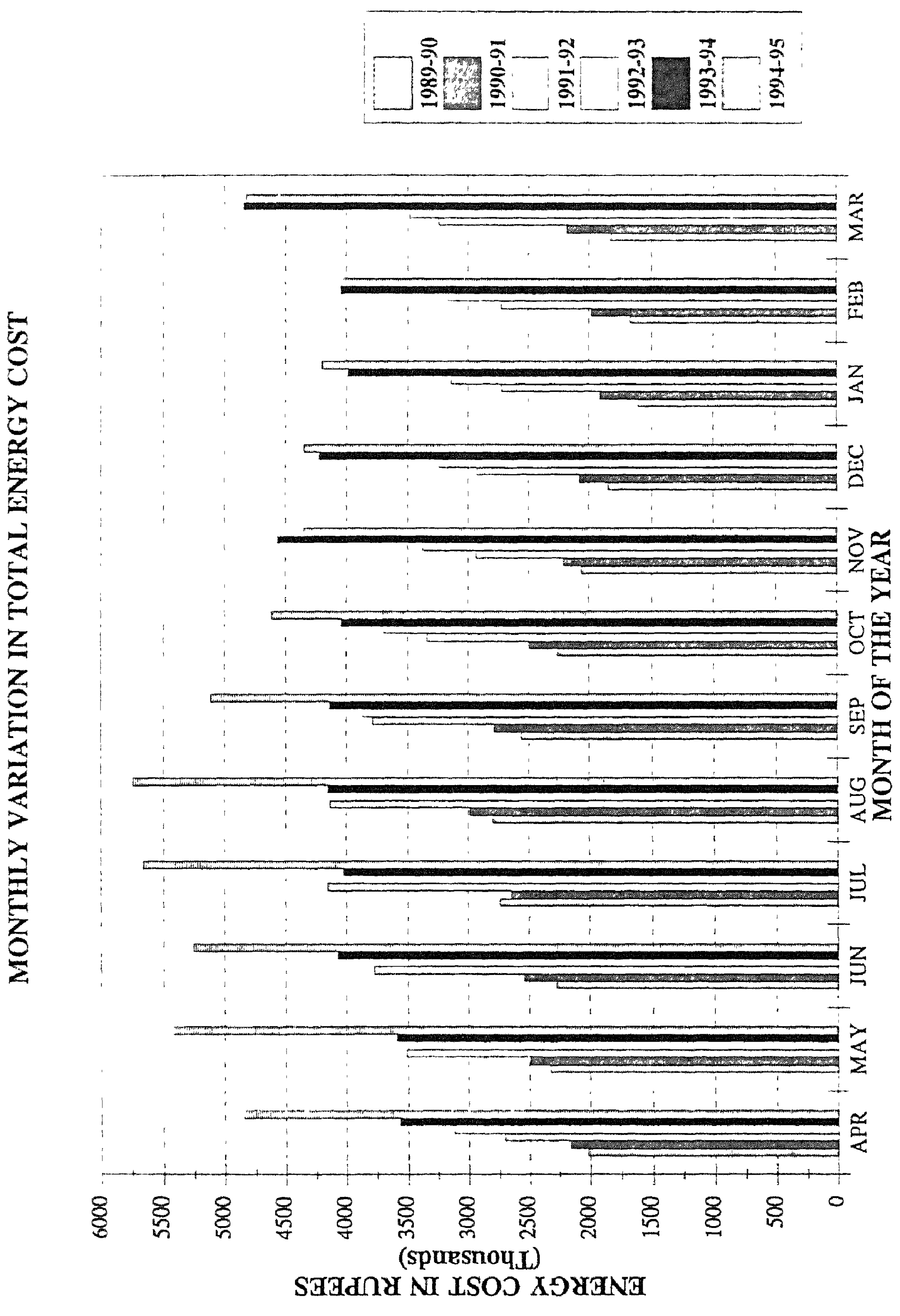

MONTHLY VARIATION IN TOTAL ENERGY COST

FIGURE 1 14

ENERGY CONSUMPTION INDICES

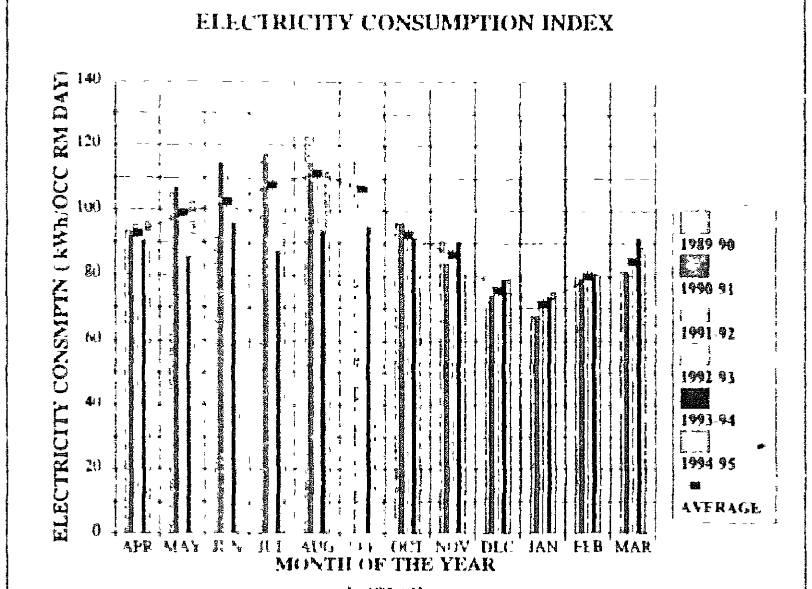


FIGURE 1.15

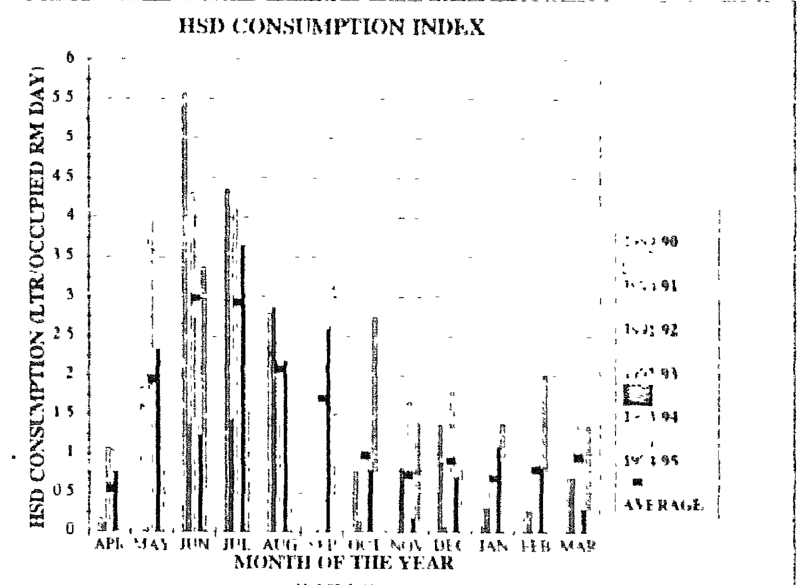


FIGURE 1.16

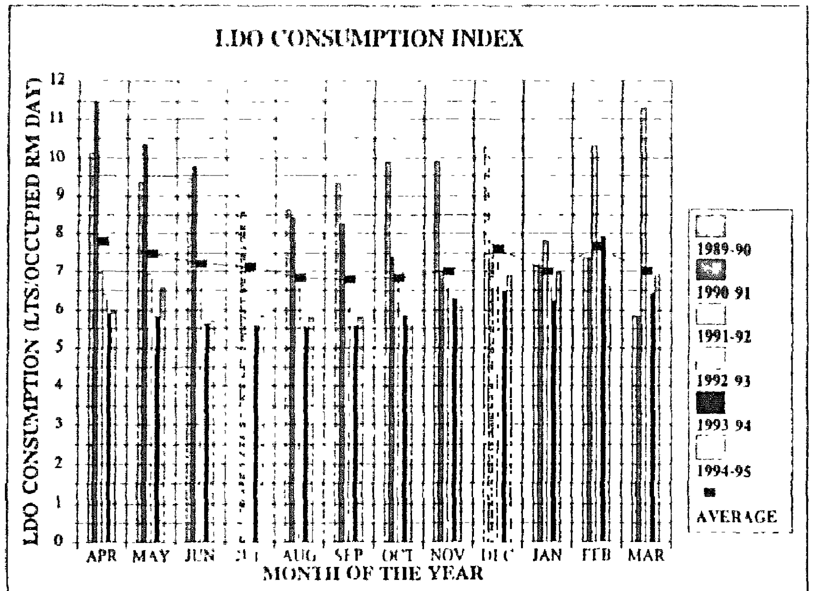


FIGURE 1.17

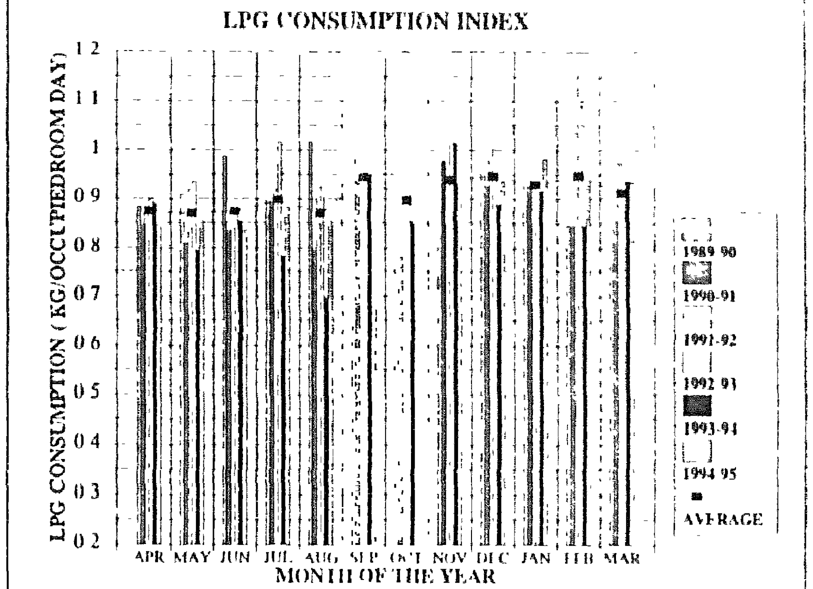


FIGURE 1.18

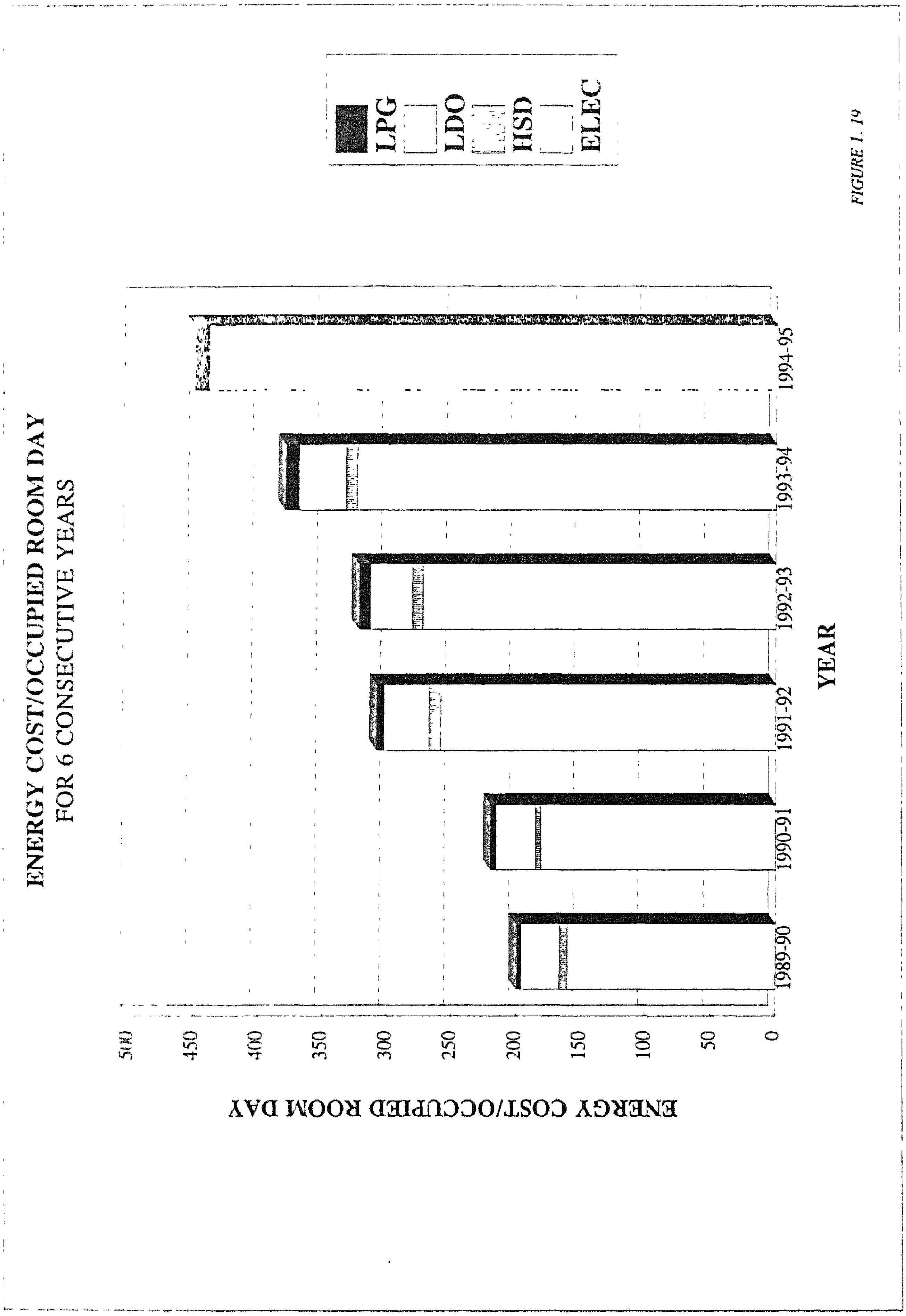

ENERGY COST/OCCUPIED ROOM DAY
FOR 6 CONSECUTIVE YEARS
ENERGY COST/OCCUPIED ROOM DAY
500
450
400
350
300
250
200
150
100
50
0
1989-90
1990-91
1991-92
1992-93
1993-94
1994-95
YEAR
LPG
LDO
HSD
ELEC

FIGURE 1.19

ENERGY CONSUMPTION INDICES

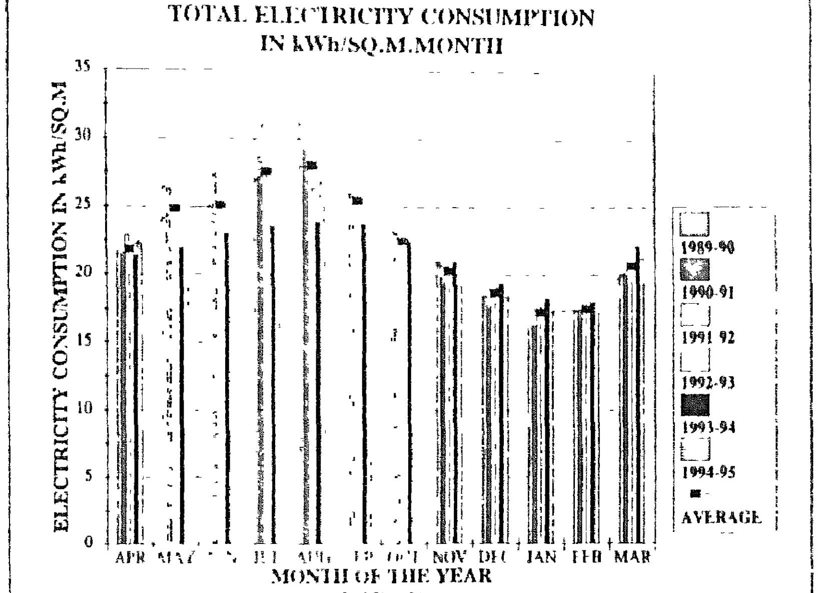


FIGURE 1.20

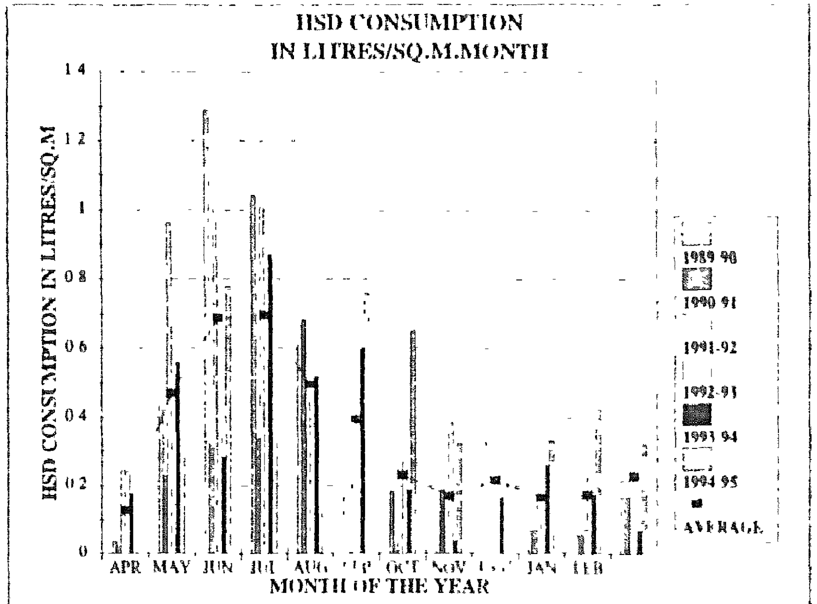


FIGURE 1.21

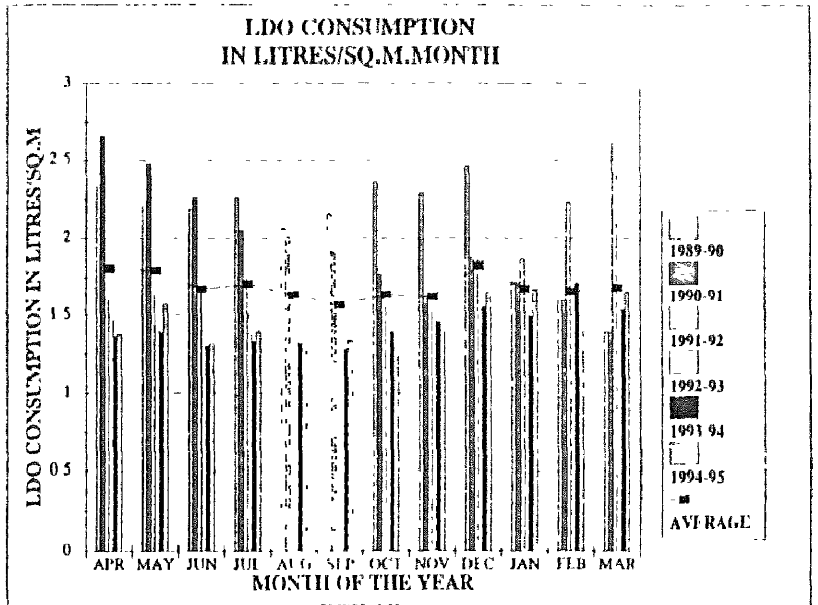


FIGURE 1.22

CHAPTER 2

Lighting Systems

The Maurya Sheraton Hotel and Towers has a total lighting connected load of 685 kW which is approximately 20.3% of the total connected load of the hotel. The power density in lighting is 14.9 W/m^2.

The areas in the hotel can functionally be divided into guest area, public area, service area, and external area. The areas under this broad divisions are as follows:

1) Guest Area

- Guest rooms
- Guest corridors
- Executive clubs
- Guest lounges

2) Service area

- Room service
- Kitchen and service
- Wash-up
- Drinks and beverage
- Maintenance
- Furniture stores
- Kitchen stores
- Offices
- Staff lockers
- Staff toilets
- Laundry
- Refuse
- Service elevators

3) Public Area

- Lobby
- Bar
- Banquet halls
- Restaurants
- Coffee shop

Guest elevators
Administration
Shopping arcade
Lobby toilets
Swimming pool area
Playing area

4) External Area

Parking
Gardens/landscaped areas

The area wise break-up of lighting load can be given as follows.

Table 2.1. Areawise break up of lighting load.

Area	kW	%
Guest area	251.86	36.8
Public area	298.14	43.5
Service area	114.38	16.7
External area	20.77	3.0

The total annual electricity consumption in lighting is approximately 24,19,400 kWh which is 22.28% of the total electricity consumption. The consumption per unit area comes to 61.5 kWh/m^2.

The areawise break-up of electricity consumption in lighting can be given as follow

Table 2.2. Areawise break-up of lighting consumption.

Area	kWh	%
Guest area	334800	13.8
Public area	1110000	45.9
Service area	951400	39.3
External area	23200	1.0

2.1 Description of Lighting Schemes in each major area

2.1.1 Guest area

The guest area is one of the major areas of a hospitality facility. The guest area comprises of guest rooms, guest corridors, executive clubs and breakfast lounges. The illumination in guest areas should be inviting and home-like. To establish such an effect, a variety of lighting equipment, some decorative in appearance is usually needed.

The Maurya Sheraton Hotel and Towers have varied types of guest rooms ranging from lavish suites to modest single/double occupancy rooms. A typical room in Maurya I is illuminated with two 40W incandescent lamps in decorative luminaries flanking the mirror, one/two decorative table lamp with 100W incandescent lamps on bed-side tables, one decorative stand lamp with 100W incandescent lamp adjacent to coffee table and one table lamp with 100W incandescent bulb on writing desk. The lobby to guest rooms typically has one 40W incandescent lamp in diffuser. Closets in some rooms are provided with 15W frosted incandescent lamp. The executive club rooms have one/two ceiling mounted 50W miniature halogen lamps in dichroic reflectors. Bar counters wherever provided have ceiling mounted miniature halogens. The toilet attached to guest room typically has two 40W tubelight in diffuser above mirror. Occasionally a 40W incandescent is provided in recessed bayonette above bath tub. The switches are separate for individual fixtures in the room. The room and toilet are each provided with cat eye infra red occupancy sensors.

The rooms in Maurya II(towers) typically have six ceiling mounted 50W miniature halogen lamps in dichroic reflector (3 nos. in room and 3 nos. lobby), four 10W picture lights for lighting the paintings, two 100W incandescent lamps in decorative luminaries as table lamp, one decorative stand lamp with 100W incandescent bulb adjacent to coffee table. The toilets have 2 miniature halogens above wash basin, two 40W incandescent lamps in cover as mirror light, one 40W incandescent lamp in cover above bath-tub and one 10W halogen for bath rack. The rooms are provided with key-tag system for lighting control.

As far as lighting in suites are concerned, each suite has its own lighting scheme. However use of **gls and 50w tungsten halogen lamps** are predominant in them.

The guest corridors are mostly illuminated by ceiling mount 50W miniature halogens in dichroic reflectors and wall mount 40W gls lamps in decorative luminaries.

The breakfast lounges in Maurya I mostly have 50W miniature halogens. The table lamps are provided with incandescent lamps and chandeliers have 25W candle lamps. The halogens and candle lights have separate dimmer controls which are operated from chief attendant's desk.

2.1.2 Service area

The service areas mainly comprises of kitchen, offices, laundry, housekeeping areas, wash areas, stores, maintenance areas, staff lockers and rest rooms, service elevators. The service area is illuminated mainly by 40W fluorescent tubelights in single/twin fixtures.

2.1.3 Public area

The public areas comprises of lobby, bar, banquet halls, restaurants, coffee shop, guest elevators, shopping arcade, lobby toilets, swimming pool & playing area.

Entertainment and food service spaces within the hospitality facility are complex and energy intensive areas in which lighting plays a key role in establishing the mood or atmosphere. Well shielded down lights, for example,can create a pleasing sparkle in reflective objects such as table settings as well as an intimate feeling. On the other hand, indirect lighting or large area diffuse sources,such as fluorescent luminaries,typically create a brighter looking space and call more attention to the whole room.

The lighting of any feature in the dining area will need special attention. These can range from highlighting of a picture or sculpture to a full luminous wall, with effects ranging from dramatic to open and friendly.

In a multi food service facility, switching, supplemental systems and/or use of dimmers may be required to make the same space feel suitable for breakfast,lunch and dinner. Variation in illumination and level may be needed, both to change the mood for different times of the day. Automatic dimming control is preferable to switching since a smooth transition between levels is desirable.

Dining spaces are usually grouped into three categories: **intimate, leisure and quick services.**

The **intimate type** includes cocktail lounges, night clubs, and some dining rooms and restaurants. These spaces have a characteristically has subdued atmosphere with low luminance throughout,accented with subtly lighted feature elements. Lighting must be well controlled in terms of level and distribution.

The **leisure-type** refers to most restaurants and many dining rooms,where eating is the most important activity and time is often a factor. Lighting should generally be unobtrusive except where decorative luminaries or highlighted features are used as a part of the theme decor. Moderate illuminance levels are required. Good glare control is required.

The **quick service** class includes lunchrooms,cafeterias,snack bars etc where the diner and manager are both intent on fast service and quick customer turnover. Higher lighting levels and uniform distribution can be used to suggest a feeling of economy and efficiency.

The lobby typically establishes the main design theme for the facility, and houses a variety of functions that can be differentiated and enhanced with appropriate lighting techniques: elevator lobby, reception desk, lounge areas, bell, captain's desk, etc. The entrance foyer is a transition space between interior and outdoor space, so foyer lighting should promote a source of security and welcome while allowing adaptation between high and lower illuminance. In lounge area both casual and prolonged reading tasks must be anticipated, though these can usually be accommodated with relatively low illuminance.

Many visual tasks are performed at the reception desk. To make this area, easy to locate and to use, the designer may choose a high general lighting level to accommodate all tasks; however a lower overall level with a system of local task lighting should be considered, especially where visual display terminal are utilized. Care should be taken that lighting be compatible with surrounding areas.

The lighting for elevator lobby areas should be designed to orient people to the elevators and should enable them to read directional signage and instructions and select proper signal controls for elevator call. Internally illuminated signage and controls are ideal.

Lighting of banquet halls which have multi-purpose use including exhibitions, conferences, meetings etc., should have a variety of lighting levels and effects. Dimming and multiple switching should be provided, organised and clearly labeled for easy operation by banquet and function personnel. Lighting must be adequate for critical tasks such as reading and note taking. Adjustable accent lighting should be provided at speaker's areas, and likely locations for displays. Outlets for local lighting should be provided in exhibit areas.

Where information television monitors are located in public spaces, care should be taken to avoid distraction or excessive vailing reflections on the monitor's tube face from luminaries, lamps with high brightness surfaces.

The food service spaces in Maurya Hotel and Towers are Dumpukht, Bukhara, Pavilion, Jazz bar, CDF, Bali-hi and Tower club. While Dumpukht, Bukhara, CDF, Bali-Hi and Tower Club form a leisure type dining area, the Jazz bar is an intimate type of food service area and the Pavilion is a quick service type of dining area. These areas are mostly lit by gls/50W miniature halogen/25W candle lights. The gls lamps and candle lamps are with/without covers. Decorative luminaries are also provided at places to enclose gls/candle lights.

The incandescent lamps have dimmer controls which are operated manually from the chief attendant's desk or front desk of the respective restaurants.

The banquet halls of Kamal Mahal have eight varied types of lighting levels and effects. They are manually controlled. The effects range from brightly lit to dimly moon-lit effect. The Sakya and Chaitya have gls and miniature halogen fixtures which are dimmable as per requirement of the function.

2.1.4 External area

The total exterior lighting system should identify the facility and create a favourable visual impression for welcoming patrons. Building facade lighting, walkway and parking lighting should be co-ordinated with signage to produce an effective coherent overall impression.

Ground of buildings should be lighted to provide for the safety of guests and property, especially in parking areas and along pedestrian paths, to eliminate areas that would otherwise be inviting to vandalism, or pose a problem in terms of security and to make accessible to the handicapped all areas of barrier-free design. Parking lights should have proper color rendition for easy vehicle identification.

In the Maurya Sheraton hotel and towers the external light is provided by 2D lamps which are energy efficient.

Table 2.3. Recommended and measured lighting levels in various areas of Maurya Sheraton hotel and towers (daytime data).

Area	*Average measured lux level*	*Recommended lux level (BIS)*	*Recommended lux level (IES)*
Guest area			
Guest room			
General	38,33,52,35,80	100	100-200
Dressing table, bedheads etc.	170,300, 150,250, 400	200	200-500
Guest corridor	75 (tower) 36 (in hotel below miniature halogens)	70	100-200
Toilet			
on wash basin	90,150,115,75	100	200-500
in bath area	8,17,12	100	100-200
Lounges	65,30,150,450,250, 300	150	100-200
Public Area			
Lobby		150	100-200
Bar	5,28	-	20-50
Restaurants	56,15,45	100	50-100 (dining area)
Coffee shop	20,30	100	50-100
Guest lift	100	70	100-200
Lobby toilet	85		100
Service Area			
Offices	15, 200	300	200-500
Laundry	100	200	200-500
Kitchen			
general	178,170,100, 38, 200		
work area	50, 250, 220, 125	200	200-500-1000
Stores	50	-	100-200
Service lifts	65	70	100-200

2.2 Energy saving options

2.2.1 Guest areas

The guest area comprises of guest rooms, guest corridors, executive clubs and executive lounges. The energy savings options for guest areas are as follows:

2.2.1.1 Guest Rooms and Toilets

Replacement of gls lamps with compact fluorescent lamps in places where the lamps are in cover and do not require dimming.

Cost benefit analysis for retrofiting a room having 2 nos. 100W gls in table lamp burning for 8 hrs/day, one 100W gls in stand lamp next to coffee table burning 8 hrs/day, 1no. 100W gls on writing table burning 8hrs/day and 2 nos. 40W gls flanking the mirror burning 8hrs/day by CFLs of comparable lumen output i.e., the 100W gls is proposed to be replaced by 20W compact fluorescent lamps (PLE/T) and 40W gls by 9W CFLs.

Table 2.4.

Cost Benefit Analysis

	GLS (100 W)	*20 W PL E/T*
Lamp cost	Rs.10 × 4	Rs.700 × 4
Life of lamp	1000h	10,000h
Electrical load	100 W	23 W
Lamp life @ 8 burning hrs/day	0.342 yrs.	3.42 yrs.
Energy consumed per annum	1168 kWh	269 kWh
Savings in energy cost per annum @ Rs.4.191/unit (x)	-	Rs.3767.71
Savings in lamp cost P.A (y)	-	Rs.116.8
Total savings P.A (x+y)	-	Rs.3884.50
Payback period	-	8 months
Net savings/lamp life of CFL for 8 burning hrs/day	-	Rs.2622.5/lamp (i.e. Rs.10,500 for 4 lamps)

Replacement of 2 no. 40W fluorescent by 2 no. 36W Trulite lamps from Phillips India which have about 30% higher lumen output than 40W ordinary tubelights.

Table 2.5.

Cost benefit analysis

	TL 40W	*Trulite 36W/86*
Cost of lamp	Rs.44.00 x 2	Rs.110.00 x 2
Operating hrs/year @ 6hrs/day	2190	2190
Unit consumed/annum	175.2 kWh	157.68 kWh
Energy cost/annum @ Rs 4.191/unit	Rs.734	Rs.660.8
Replacement/annum @ 5000 hrs. rated lamp life	0.438	0.438
Cost of replacement/annum	38.54	96.36
Running cost/annum	772.54	757.16
Saving in running cost	-	Rs.15.38
Excess in investment	-	Rs.132
Payback		8 years 7 months

This option though not economically very lucrative, has an advantage of giving 30% more in terms of lumen output.

2.2.1.2. Guest corridors

Regulated dimmers linked to occupancy sensors for guest corridors.
The guest corridors are mostly lit by incandescent lamps and miniature halogen lamps. They could be equipped with regulated dimmers linked to occupancy sensors. The dimmers can have a set point to operate lamps at 80% load when occupancy is not sensed. At present 777 miniature halogen of corridor in the hotel and towers are timer controlled and are switched off between 11 pm to 6 am i.e., for 7 hrs. Rest of the time i.e., for 17 hrs all lights are kept on.

Let us assume that for about 10hrs/day of these 17hrs and for about 5hrs between 11pm to 6 am there is no movement along the corridors.

Hence 777 miniature halogens of 50W rating and 680 gls of 40W each could be operated at 80% load during those times. Hence total savings achieved in one year would be

$$\left[\frac{0.2\ (777 \times 50 + 680 \times 40) \times 10 + 0.2\ (680 \times 40) \times 5}{1000}\right] \times 365 kWh = 58144.5 kWh/yr$$

i.e. Rs.2,43,684/year @ Rs.4.191/unit

Replacement of 40W gls by 15W PL E/T lamp in guest corridors.
There are about 680 nos.40 W gls lamps is guest corridors which are under 24 hrs operation.

Table 2.6.

Cost Benefit Analysis

	GLS (40 W)	*15 W PL E/T*
Lamp cost	Rs 10 × 680	Rs 650 × 680
Life of lamp	1000h	10 000h
Electrical load	40 W	18 W
Lamp life @ 24 burning hrs/day	0.114yrs.	1.14 yrs.
Energy consumed per annum	238272 kWh	10722.4 kWh
Savings in energy cost per annum @ Rs 4 191/unit (x)	-	Rs 5 49 229
Savings in lamp cost P.A (y)	-	Rs 59 568
Total savings P.A (x+y)	-	Rs 6 08 797
Payback period	-	9 months
Net savings/lamp life of CFL for 24 burning hrs/day	-	Rs 370.6/lamp (i.e.total of Rs 2 52 008

2.2.1.3. *Breakfast Lounges and Executive Clubs*

The breakfast lounges and executive clubs have external exposure with glazing on one side. Hence it was found that near to window there is a sharp increase in illumination level and (to about 600 lux in comparison to 70-80 lux away from window). Dimmers, though provided, being manually controlled, is seldom used during daytime until specifically requested for.

Hence, it is proposed to have photo cells near to external window which can sense natural light and dim and brighten the lights adjacent to window, during daytime. Automatic photocell control saves at least 30% of energy for lighting adjacent to windows.

2.2.2. *Service areas*

2.2.2.1. *Replacement of 40W fluorescent tubelights by 36W Trulite.*

The service area is mostly lit by 40W tubelights in single or twin fixtures. Conventional magnetic ballast are being provided. In most of the service area the tubelights have 24 hour use. The service area have a connected load of 114.38kW. Of this the fluorescent fixture account for 83.34kW the connected load. The 40W fluorescent lamps could be replaced by 36W Trulite lamps which give 30% more in lumen output.

Table 2.6. Cost benefit analysis

Operating hours/day	*Connected load (kW)*	*Approx no.of 40W TL*	*No. of replacements per annum @ 5000hrs of lamp life*	*Replacement cost per annum of 40W TL @ Rs 44/lamp*	*Replacement cost per annum of 36W Trulite @ Rs 110/ lamp*
8	1.84	46	0.584	1182	2955.04
10	6.92	173	0.73	5556.76	13891.9
12	3.76	94	0.876	3623.136	9057.84
15	0.08	2	1.095	96.36	240.9
14	4.2	105	1.022	4721.64	11804.1
16	2.08	52	1.168	2672.384	6680.96
18	4.98	124	1.314	7169.184	17922.96
20	15.66	391	1.46	25117.84	62794.6
22	2.38	59	1.606	4169.176	10422.94
24	41.44	1036	1.752	79863.168	199657.92
Total	83.34	2082		1,34,171.648	3,35,429.16

The 40W TL lamps could be replaced by 36W Trulite lamps. Hence there would be 4W savings in connected load/installed tubelight.

Annual savings in kWh can be calculated as follows:

$$\frac{(46\times8+173\times10+105\times14+52\times16+124\times18+391\times20+59\times22+1036\times24+94\times12+2\times15)\times4\times365}{1000}$$

= 60987.12 kWh

i.e., Rs 2 55 600/year.

The excess expenditure incurred per year in replacing lamp is **Rs 2 01 257. Hence payback is 9½ months.**

This option has an added advantage of giving 30% more in terms of lumen output.

2.2.2.2. Replacement of conventional magnetic ballast by electronic ballast in twin fixtures.

Assuming that out of 2082 tubelights, 60% are in twin fixtures, then about 1250 lamps are housed in 625 twin fixtures using magnetic ballast. Wattage loss in case of use of magnetic ballast is about 15W/ballast. Hence for a twin lamp fixture, there is a loss of 30W as against 3W in case of electronic ballast. Hence there is a saving in kWh assuming an average burning of 16hr/fixture per day is.

$$\frac{625 \times 16 \times 27 \times 365}{100} = 98550 \text{ kWh}$$

i.e., Rs.4,13,023.00 (@ Rs.4.191/unit)

The investment required is **Rs. 4,68,750** (@ Rs.750/HF ballast for twin fixture).

2.2.3. Public areas

The public areas comprises of lobby, bar, banquet halls, restaurants, coffee shop, guest elevators, lobby toilets, swimming pool and playing area.

The public area is mostly lit by incandescent lamps (gls and miniature halogens). The gls lamps wherever installed are either in transparent/translucent cover or are without covers. Some of these lamps are required to be dimmed whereas some do not require so.

Energy saving options have been worked out for a select list of areas where the saving potential exists. For other areas, the savings could be worked out on similar lines.

2.2.3.1. Dumpukht restaurant

Dimming during preparation/cleaning.

Dumpukht restaurant has a connected load of 7.349 kW. The total operation hours is 10hrs and the cleaning and preparation time is 4 hrs daily. All lights are kept fully on for the period of 14hrs. Dimmers though installed are rarely operated. However, if for the period of 4 hrs (i.e., cleaning and preparation time) the lights are dimmed to operate at 80% load, then the annual savings achieved could be.

0.2 x 7.349 x 365 x 4 = 2146 units/year

i.e., Rs 9000 @ Rs 4.191/unit can be achieved annually at no additional investment.

There are 9 miniature halogens located next to window which were kept on during daytime. Considering 7 hours of operation/cleaning/preparation time during daytime, these lamps can be switched off during daytime. The savings achieved therefrom could be quantified as.

$$\frac{9 \times 50 \times 7 \times 365}{1000} = 1150 \text{ units/year.}$$

i.e., Rs 4900/annum @ Rs 4.191/unit.

2.2.3.2 Bukhara

Dimming during preparation/cleaning.The Bukhara restaurant has almost all gls lamps. The connected load is 10.9 kW. The duration of operation is 10hrs/day and cleaning and preparation time is 4 hrs. The lights are dimmed only between 4.30pm to 6.30 pm. The lights could be dimmed to operate at 80% load during cleaning/preparation time.

The annual savings achieved thereof could be calculated as.

10.9 x 0.2 x 4 x 365 = 3182 8 units/year

i.e., Rs 13 339/year @ Rs 4 191/unit.

Similarly, for **Bali-Hi and CDF restaurants** having a combined connected load of of 15.21 kW (all incandescent) and having a cleaning/preparation time of 3 hrs each, the savings obtained by dimming during preparation/cleaning time would bring about savings of.

0.2 x 15.21 x 3 x 365 = 3330.99 kWh/year

i.e. Rs 14 000 @ Rs 4 191/unit

2.2.3.3. Pavilion (coffee shop)

Replacement of 40 W gls by 15 W PL(E/T). In the 24hr coffee shop, there are about 55 no. of 40W incandescent bulbs which could be replaced by 15W PL E/T lamps.

Table 2.7.

Cost Benefit Analysis

	GLS (40 W)	*15 W PL E/T*
Lamp cost	Rs 10 × 55	Rs 650 × 55
Life of lamp	1000h	10 000h
Electrical load	40 W	18 W
Lamp life @ 24 burning hrs/day	0.114 yrs.	1.14 yrs.
Energy consumed per annum	19272 kWh	8672.4 kWh
Savings in energy cost per annum @ Rs 4 191/unit (x)	-	Rs 44 422.9
Savings in lamp cost P.A (y)	-	Rs 4818
Total savings P.A (x+y)	-	Rs 49 241
Payback period	-	9 months
Net savings/lamp life of CFL for 24 burning hrs/day	-	Rs 370.6/lamp (i.e.total of Rs 20 384)

2.2.3 4. Lobby

The Maurya I lobby has about 173 nos. 40W clear incandescent lamps, 235 nos. 40W milky incandescent lamps and 6 nos. 100 W clear incandescent lamps. All of these have 24-hr. operation. It is proposed to replace the 40 W milky incandescent lamps by 15W PL E/T lamps. The cost benefit analysis works in the same way as in case of similar replacement in guest corridors. However, in this case, there are about 235 lamps to be replaced. The total savings works out to be Rs 2 10 393.The payback period remains to 9 months.

The Maurya II (towers) lobby also has 141 nos. 40 W milky incandescent lamps under 24 hr use which could be replaced by 15W PL E/T lamps.

CHAPTER 3

HVAC Systems

3.1 Load & Consumption Pattern

The total installed capacity of the air conditioning plant at Maurya Sheraton Hotel and Towers is over 1200 TR. This comprises of four main central air-conditioning systems each of 300 TR capacity. In installed HVAC load which is 46.8% of the total connected load (Figure 3.1), compressors contribute to the maximum load (53.6%) followed by air handling units (20.4%). The pumps account for 17.8% of the load while the share of Fan Coil Units and Cooling Tower fans are 4.2% & 4% respectively (Figure 3.2).

The HVAC load undoubtedly is the largest load centre at Maurya Sheraton Hotel & Towers accounting for the major electricity consumption. The share of the electricity consumption of the air-conditioning system is estimated to be 39.8% of the total electricity consumption in Maurya Sheraton Hotel & Towers (Figure 3.3). Equipment-wise breakup of HVAC consumption (Figure 3.4) shows that the maximum consumption is in compressors (42.3%), pumps and CT fans consume 34.1%, while the AHUs and FCUs take 13.5% and 9.7% of the total input energy respectively.

The above clearly demonstrates the importance of the HVAC system in Maurya Sheraton hotel and towers and the benefits that can be derived by improving its operating efficiency. Keeping this in view, a detailed analysis of the chiller units has been carried out. For the central chiller units, the present study evaluates the performance of the chiller machines, the air handling units (AHUs), the cooling towers and other auxiliaries like chilled water/condenser water pumps etc. The details of various measurements taken, observations made, the analysis of the results and the measures to improve the energy efficiency of the system as a whole is presented in the following sections.

3.2 System Details

The main central plant consists of four identical 300 TR chilled water systems. Some selected details of the system are outlined below:

3.2.1 300 TR Chilled Water System

3.2.2.1 Compressor

The compressor is single stage high speed centrifugal type **carrier** make. Refrigerant used is R-11. Capacity is controlled by microprocessor-based control systems. Micro processor-based controls can be programmed to start and stop a chiller automatically at

SYSTEMWISE BREAKUP OF
TOTAL CONNECTED LOAD

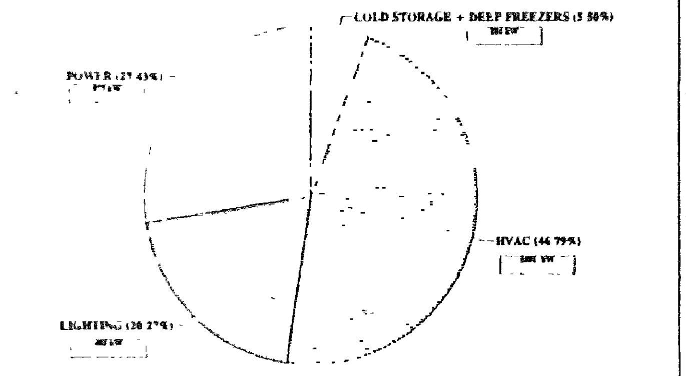


FIGURE 3 1

EQUIPMENTWISE BREAKUP OF
HVAC CONNECTED LOAD

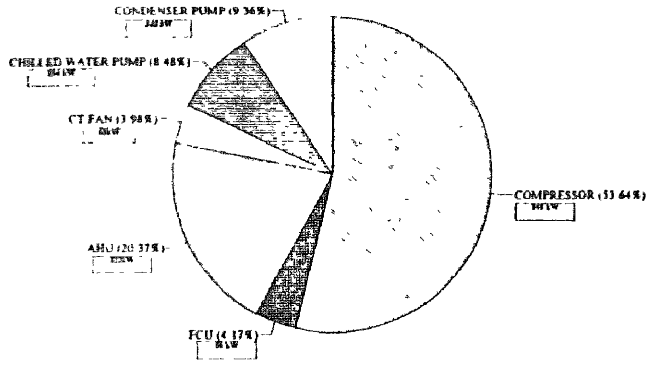


FIGURE 3 2

SYSTEMWISE BREAKUP OF
ELECTRICITY CONSUMPTION

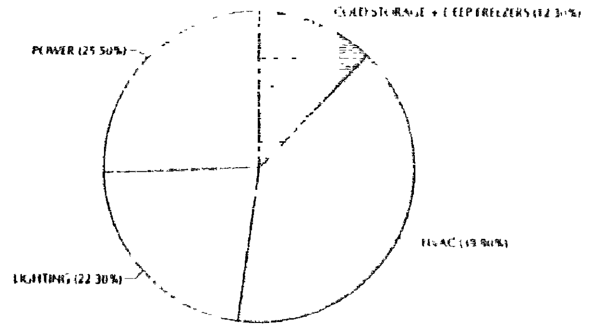


FIGURE 3 3

EQUIPMENTWISE BREAKUP OF
HVAC CONSUMPTION

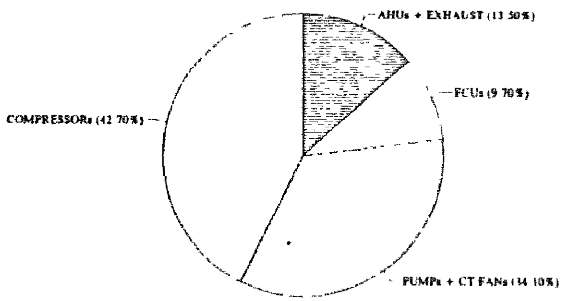


FIGURE 3 4

different times of the day, on different days of the week. The chiller controls can also operate the cooling tower fans and the condenser/chilled water pumps. At start up, the chilled-water temperature's pull down rate and the pull down motor current can be programmed to limit electric power demand costs. The status of any of the system monitoring parameters (pressures, temperature etc) can be obtained from an alphanumeric display on the microprocessor control panel. The set points of the controls can also be read and compared with the measured operating values.

3.2.2.2 *Compressor Motor*

The compressor is driven by a carrier make, unishell induction motor provided with a star delta starter.

3.2.2.3 *Evaporators (Chillers)*

Horizontal shell and tube evaporators are being used in centrifugal chiller. These are of the flooded typed with liquid refrigerant surrounding the tubes. The chilled water flows inside the tubes. The tube bundle occupies only the lower part of the shell, the upper part is a space in which liquid refrigerant drops out of the vapour that is flowing to the compressor.

3.2.2.4 *Condenser*

Horizontal shell and tube condenser has been used with the cooling water inside the tubes. The tube bundle fills most of the shell. The outside surface of the tubes is finned to increase refrigerant-side transfer.

3.2.2.5 *Air Handling Units*

Chilled water is circulated in 65 air handling units which cater to the various load requirements of the Hotel. The AHUs are of Voltas make and of different capacities (AH3 to AH11). In most of the AHUs number of fins in cooling coils are reduced to 10 from 12 or 13 fins per inch for ease in cleaning and better maintenance.

3.2.2.6 *Cooling Towers*

Condenser water is cooled by two cross-flow induced draft cooling tower one of Paharpur make with three bays and another one is of Voltas make with one bay. The details of technical specifications of compressor and the auxiliaries are provided in Annexure 1.

3.3 Measurements and Observations

3.3.1 300 TR Chiller

The operating parameters of all the four 300 TR chilling machines have been studied over a period of time. Measurements were taken in two conditions (i) before tube cleaning and (ii) after tube cleaning of the condensers. The key operational parameters are listed in table 3.2. Chilled water flow rates of chillers were estimated corresponding to the pressure drop across the chillers and also from the pump characteristics for the pressures developed by the chiller pumps. The estimated flow rate through the chiller no.1 and 2 was 1058 US gpm and through the chilller no 3 & 4 was 985 US gpm as against the rated chilled water flow of 899 US gpm. The full load and part load performances of each chiller have been studied thoroughly. Measurements were carried out to find out the power input to the compressor motor and the cooling capacity of the machine at different operating conditions. The specific powers & COPs have been calculated and the complete analysis is summarised in tables given below. The power consumptions of the compressor corresponding rated loads, specific powers and COP as per the test documents are given in table 3.1.

Table 3.1. Specific Power and COP of 300TR Chiller at rated loads.

1.	Vane opening (100%)	100	75	50	25
2.	Rated load (TR)	300	225	150	75
3.	Chiller Input (Kw)	212	141	90	50
4.	**Specific power (Kw/TR)**	**0.708**	**0.627**	**0.600**	**0.669**
5.	**COP**	**4.97**	**5.61**	**5.87**	**5.26**

Table 3.2. Specific Power & COP of Chiller No. 1 at operating loads (Before tube cleaning).

S. No.	Parameters	*Operating conditions*		
1.	Vane opening	100%	75%	60%
2.	Entering chilled water temp (F)	55.8	55.4	56.3
3.	Leaving chilled water temp (F)	49.5	50.54	52.7
4.	Evaporating pressure	14"Hg vac	13" Hg vac	12" Hg vac.
5	Evaporating temp. (F)	42.8	44.6	46.4
6	Condensing pressure (psig)	11.5	10	9
7	Condensing Temperature (F)	102.2	98.6	96.8
8.	Entering condenser water temp. (F)	89.4	89.2	89.2
9.	Leaving condenser water temp. (F)	95.5	93.6	92.5
10.	Water side pressure drop in evaporator	15	15	15
11.	Chilled water flow rate (US gpm)	1058	1058	1058
12.	Voltage (V)	402	391	371
13.	Current drawn by compressor motor (A)	326.9	245.7	204.2
14.	Power Factor	0.861	0.843	0.835
15.	Input Kw of compressor motor	194	164	108
16.	Cooling capacity of chiller (TR)	278	214	158.7
17.	**Specific Power (Kw/TR)**	**0.700**	**0.65**	**0.68**
18.	**Coefficient of Performance (COP)**	**5.03**	**5.41**	**5.18**

Table 3.3. Specific Power & COP of Chiller No.1 at operating loads (After tube cleaning).

S. No.	Parameters	*Operating conditions*				
1.	Vane opening	100%	90%	80%	70%	60%
2.	Entering chilled water temp (F)	50.5	50.5	51.7	53.3	55.5
3.	Leaving chilled water temp (F)	44.2	44.5	46.6	48.7	51.9
4.	Evaporating pressure(Hg vac)	16"	15"	15"	15"	13"
5.	Evaporating temp. (F)	35.6	35.6	37.4	39.2	44.6
6.	Condensing pressure (psig)	9.5	9.5	8	8	6.5
7.	Condensing Temperature (F)	100.4	98.6	96.8	95	89.6
8.	Entering condenser water temp. (F)	90.1	89.6	89.3	88.3	85.6
9.	Leaving condenser water temp. (F)	96.4	95	94.3	92.3	89
10.	Water side pressure drop in evaporator (psig)	15	15	15	15	15
11.	Chilled water flow rate (US gpm)	1058	1058	1058	1058	1058
12.	Voltage (V)	405	443	3.89	393	400
13.	Current drawn by compressor motor (A)	323.8	298.6	263.4	235.6	195.8
14.	Power Factor	0.859	0.861	0.853	0.835	0.776
15.	Input Kw of compressor motor	195	185	150	133	104
16.	Cooling capacity of chiller (TR)	277.7	264.5	224.8	198.4	158.7
17.	**Specific Power (Kw/TR)**	**0.702**	**0.699**	**0.667**	**0.670**	**0.654**
18.	***Coefficient of Performance (COP)***	**5.01**	*5.03*	*5.28*	*5.25*	*5.38*

Table 3.4. Specific Power & COP of Chiller No. 2 at operating loads (Before tube cleaning).

S. No.	Parameters	*Operating conditions*		
1.	Vane opening	100%	75%	60%
2.	Entering chilled water temp (F)	56.7	55.8	56.5
3.	Leaving chilled water temp (F)	49.5	50.54	52.3
4.	Evaporating pressure (Hg vac)	10"	9"	8"
5.	Evaporating temp. (F)	41	42.8	46.4
6.	Condensing pressure (psig)	12	10.5	8.5
7.	Condensing Temperature (F)	105.8	100.4	96.8
8.	Entering condenser water temp. (F)	90.1	489.6	89.6
9.	Leaving condenser water temp. (F)	96.4	94.3	93.2
10.	Water side pressure drop in evaporator (psig)	15	15	15
11.	Chilled water flow rate (US gpm)	1058	1058	1058
12.	Voltage (V)	411	411	412
13.	Current drawn by compressor motor (A)	364.7	275.5	227.2
14.	Power Factor	0.854	0.820	0.772
15.	Input Kw of compressor motor	221	160	124
16.	Cooling capacity of chiller (TR)	314.4	238	182.5
17.	**Specific Power (Kw/TR)**	**0.70**	*0.67*	**0.68**
18.	***Coefficient of Performance (COP)***	**5.03**	*5.25*	**5.18**

Table 3.5. Specific Power & COP of Chiller No.2 at operating loads (After tube cleaning).

S. No.	Parameters	**Operating conditions**				
1.	Vane opening	100%	90%	80%	70%	60%
2.	Entering chilled water temp (F)	50.1	50.6	52.5	53.3	55.8
3.	Leaving chilled water temp (F)	44.3	44.8	47.1	48.7	51.8
4.	Evaporating pressure (Hg vac)	12"	11"	10.5"	10"	9"
5.	Evaporating temp. (F)	35.6	35.6	37.4	39.2	44.6
6.	Condensing pressure (psig)	9.5	9	8.5	7.5	6.5
7.	Condensing Temperature (F)	98.6	98.6	96.8	93.2	91.4
8.	Entering condenser water temp. (F)	90.5	89.6	89.4	87	85.4
9.	Leaving condenser water temp. (F)	96.2	95.4	94.5	91.7	89.4
10.	Water side pressure drop in evaporator (psig)	15	15	15	15	15
11.	Chilled water flow rate (US gpm)	1058	1058	1058	1058	1058
12.	Voltage (V)	400	391	387	394	400
13.	Current drawn by compressor motor (A)	363.3	332.1	292.1	260.5	220.5
14.	Power Factor	0.876	0.872	0.866	0.849	0.812
15.	Input kW of compressor motor	222	195	168	150	123
16.	Cooling capacity of chiller (TR)	255.7	255.6	233.8	202.8	176
17.	**Specific Power (kW/TR)**	**0.868**	**0.763**	**0.719**	**0.740**	**0.700**
18.	**Coefficient of Performance (COP)**	**4.05**	**4.61**	**4.89**	**4.76**	**5.03**

Table 3.6. Specific Power & COP of Chiller No. 3 at operating loads (Before tube cleaning).

S. No.	Parameters	*Operating conditions*		
1.	Vane opening	100%	75%	60%
2.	Entering chilled water temp (F)	53.2	54.1	54.9
3.	Leaving chilled water temp (F)	46.6	49.1	50.7
4.	Evaporating pressure (Hg vac)	16"	14.5"	14.0"
5.	Evaporating temp. (F)	39.2	42.8	44.6
6.	Condensing pressure (psig)	12	9.5	7.5
7.	Condensing Temperature (F)	105.8	98.6	95
8.	Entering condenser water temp. (F)	86.9	86.4	85.5
9.	Leaving condenser water temp. (F)	93.2	91.4	89.2
10.	Water side pressure drop in evaporator (psig)	13	13	13
11.	Chilled water flow rate (US gpm)	985	985	985
12.	Voltage (V)	377	364	364
13.	Current drawn by compressor motor (A)	331.1	252.5	199.4
14.	Power Factor	0.878	0.874	0.835
15.	Input kW of compressor motor	188	138	104
16.	Cooling capacity of chiller (TR)	273	207	170
17.	**Specific Power (kW/TR)**	**0.69**	**0.67**	**0.612**
18.	**Coefficient of Performance (COP)**	**5.1**	**5.25**	**5.75**

Table 3.7. Specific Power & COP of Chiller No. 3 at operating loads (After tube cleaning).

S. No.	Parameters	*Operating conditions*				
1.	Vane opening	100%	90%	80%	70%	60%
2.	Entering chilled water temp (F)	49.7	49.7	50.0	49.8	50.4
3.	Leaving chilled water temp (F)	43.2	43.8	44.2	45	46.5
4.	Evaporating pressure (Hg vac)	17.5"	17"	16"	16"	15"
5.	Evaporating temp. (F)	35.6	35.6	37.4	37.4	41
6.	Condensing pressure (psig)	9.5	9	8	7.5	7
7.	Condensing Temperature (F)	100.4	98.6	96.8	96.8	93.2
8.	Entering condenser water temp. (F)	91.9	91.9	90.8	89.8	89.7
9.	Leaving condenser water temp. (F)	97.5	96.5	95.6	94.1	92 9
10.	Water side pressure drop in evaporator (psig)	13	13	13	13	13
11.	Chilled water flow rate (US gpm)	985	985	985	985	985
12.	Voltage (V)	392	404	410	414	398
13.	Current drawn by compressor motor (A)	342.8	295.2	265.9	239	229.7
14.	Power Factor	0.873	0.851	0.826	0.804	0.797
15.	Input kW of compressor motor	203	175	156	138	112
16.	Cooling capacity of chiller (TR)	266.8	242.1	238	197	160
17.	**Specific Power (kW/TR)**	**0.761**	**0.723**	**0.655**	**0.701**	**0.70**
18.	**Coefficient of Performance (COP)**	**4.62**	**4.87**	**5.37**	**5.02**	**5.03**

Table 3.8. Specific Power & COP of Chiller No. 4 at operating loads (Before tube cleaning).

S. No.	Parameters	*Operating conditions*		
1.	Vane opening	100%	75%	60%
2.	Entering chilled water temp (F)	53.2	5.9	65.5
3.	Leaving chilled water temp (F)	46.8	50.9	52.5
4.	Evaporating pressure (Hg vac)	16"	15.5"	13.5"
5.	Evaporating temp. (F)	37.4	41	44.6
6.	Condensing pressure (psig)	12	10.5	10
7.	Condensing Temperature (F)	104	100.4	98.6
8.	Entering condenser water temp. (F)	91.2	90.7	91.2
9.	Leaving condenser water temp. (F)	97.0	95.2	94.6
10.	Water side pressure drop in evaporator (psig)	12	12	12
11.	Chilled water flow rate (US gpm)	946	964	946
12	Voltage (V)	397	380	401
13	Current drawn by compressor motor (A)	338.7	256.7	206.5
14	Power Factor	0.801	0.821	0.757
15	Input kW of compressor motor	165	128	102
16.	Cooling capacity of chiller (TR)	255	198.7	156
17.	**Specific Power (kW/TR)**	**0.65**	**0.64**	**0.654**
18.	**Coefficient of Performance (COP)**	**5.41**	**5.5**	**5.38**

Table 3.9. Specific Power & COP of Chiller No. 4 at operating loads (After tube cleaning).

S. No.	Parameters	*Operating conditions*				
1.	Vane opening	100%	90%	80%	70%	60%
2.	Entering chilled water temp (F)	56.3	49.8	50.2	56.2	52.4
3.	Leaving chilled water temp (F)	50.6	44.4	45.2	51.4	48.7
4.	Evaporating pressure (Hg vac)	16"	16.5"	16"	14"	15"
5.	Evaporating temp. (F)	39.2	33.8	35.6	42.8	39.2
6.	Condensing pressure (psig)	10.5	9.5	9.5	10	8.5
7.	Condensing Temperature (F)	100.4	98.6	98.6	98.6	96.8
8.	Entering condenser water temp. (F)	91.8	90.2	90.1	90.8	89.8
9.	Leaving condenser water temp. (F)	98	95.2	94.8	95.3	93.3
10.	Water side pressure drop in evaporator (psig)	13	13	13	13	13
11.	Chilled water flow rate (US gpm)	985	985	985	985	985
12.	Voltage (V)	381	401	381	395	402
13.	Current drawn by compressor motor (A)	337.7	307.7	272.8	243.1	216.8
14.	Power Factor	0.88	0.856	0.869	0.831	0.792
15.	Input kW of compressor motor	195	182	155	137	118
16.	Cooling capacity of chiller (TR)	233.9	221.6	205.2	197	152
17.	**Specific Power kW/TR**	**0.834**	**0.821**	**0.755**	**0.695**	**0.776**
18.	**Coefficient of Performance (COP)**	**4.22**	**4.29**	**4.66**	**5.06**	**4.53**

The specific power and COP of the chiller machine at different rated loads are shown in (Figure 3.5).

The comparison of specific powers & COPs of chiller plants at rated loads & operating loads is shown in (Figure 3.6). It has been observed that the COP of all the chillers at full load before tube cleaning were more than the rated COP but after tube cleaning the COP of Chiller No.2, Chiller no.3 & Chilller no. 4 became less than the rated COP while the COP of chiller no 1 remained more than the rated COP as shown in (Figure 3.6).

Specific powers and COPs of all chillers at operating loads, before tube cleaning and after tube cleaning, are also shown in (Figure 3.7) and (Figure 3.8).

3.3.2 *Air Handling Units (AHUs) & Fan Coil Units (FCUs)*

The Air handling units have been studied for its performance. There are 65 AHUs and approximately 811 FCUs of different capacities installed in Maurya Hotel & Towers. Number of units installed, model and other characteristics are given below in tables 3.10 & 3.11.

Table 3.10. Air Handling Units (AHUs)

S.No.	Model	*Number*	*Make*	*Rated Capacity (TR)*	*Rated CFM (at 500 fps)*	*Motor rating (HP)*
1	AH - 3	16	Voltas	7.5	3050	3
2	AH - 5	3	Voltas	12	4125	3
3	AH- 6	11	Voltas	16	5600	5
4	AH - 7	16	Voltas	25	8750	7.5
5	AH - 9	15	Voltas	30	11300	10
6	AH - 11	4	Voltas	45	17000	12.5

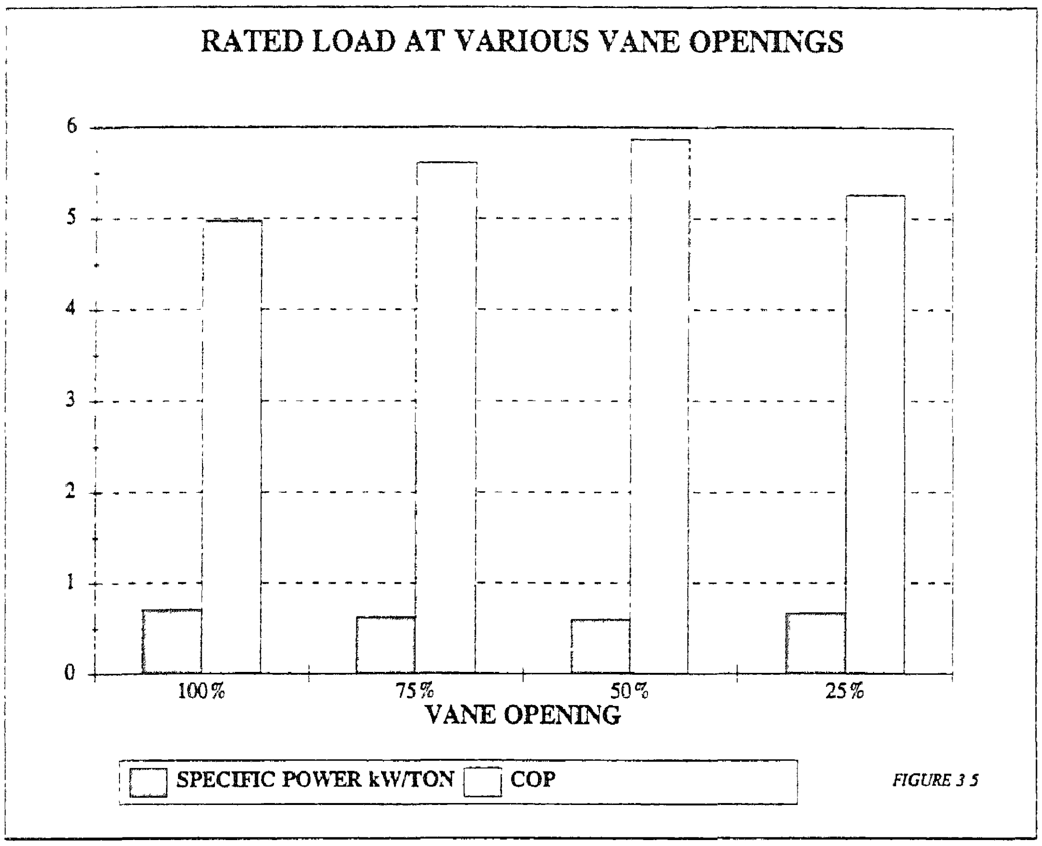


FIGURE 3.5

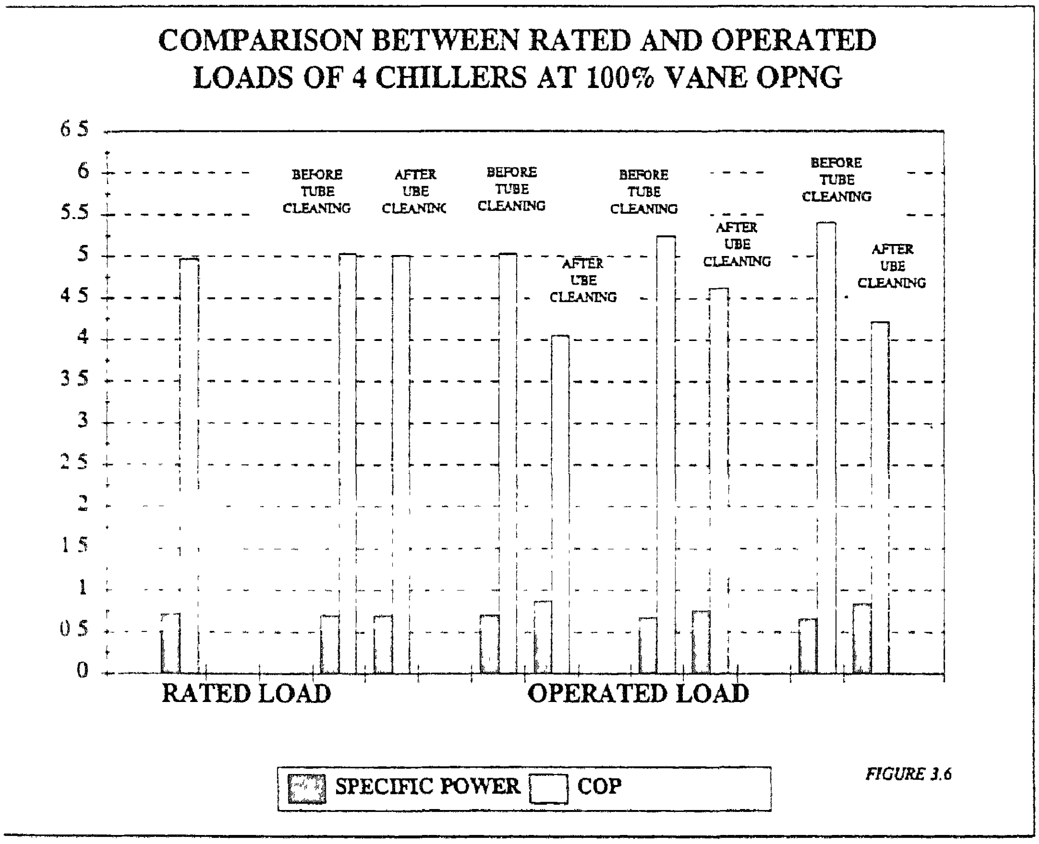


FIGURE 3.6

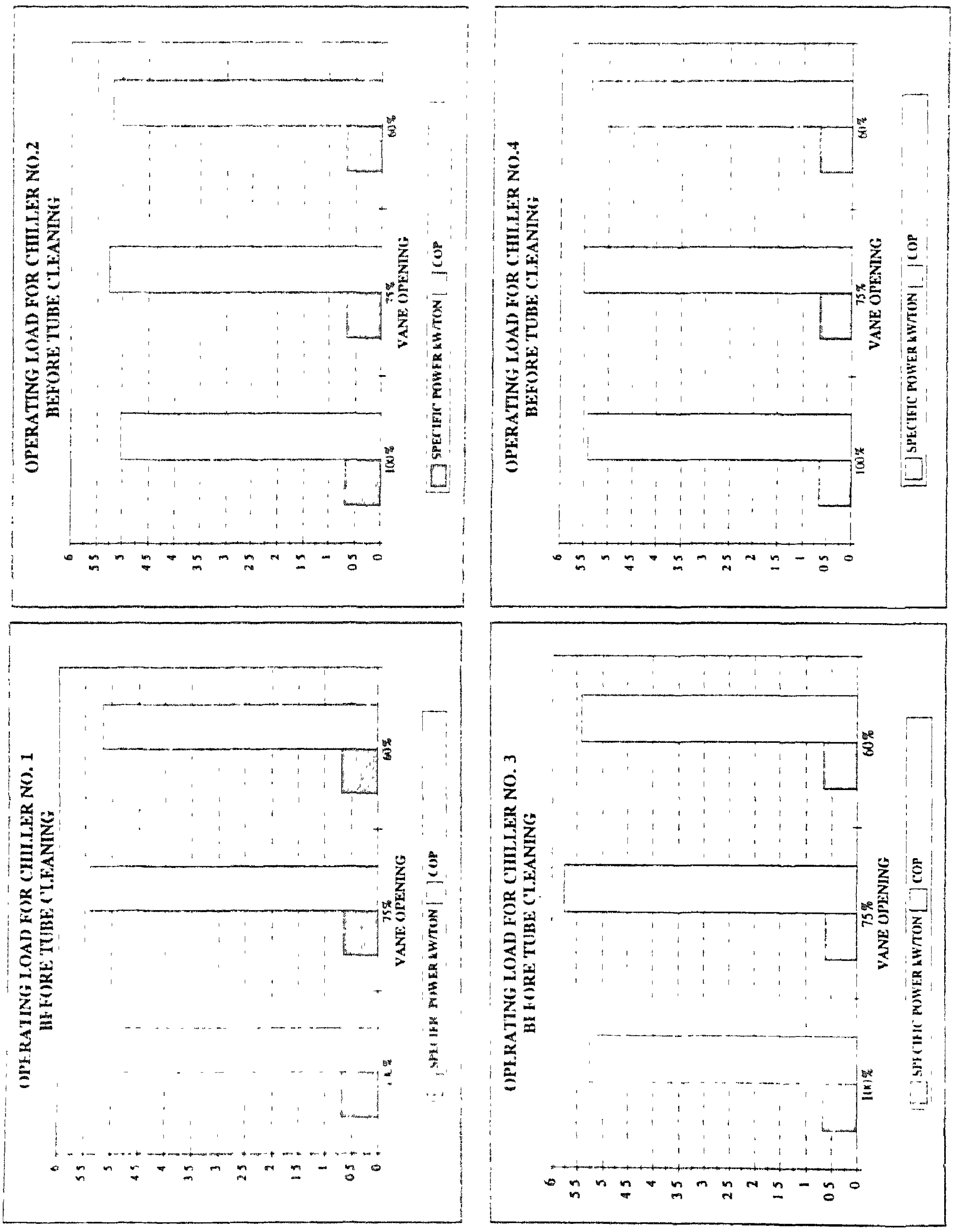
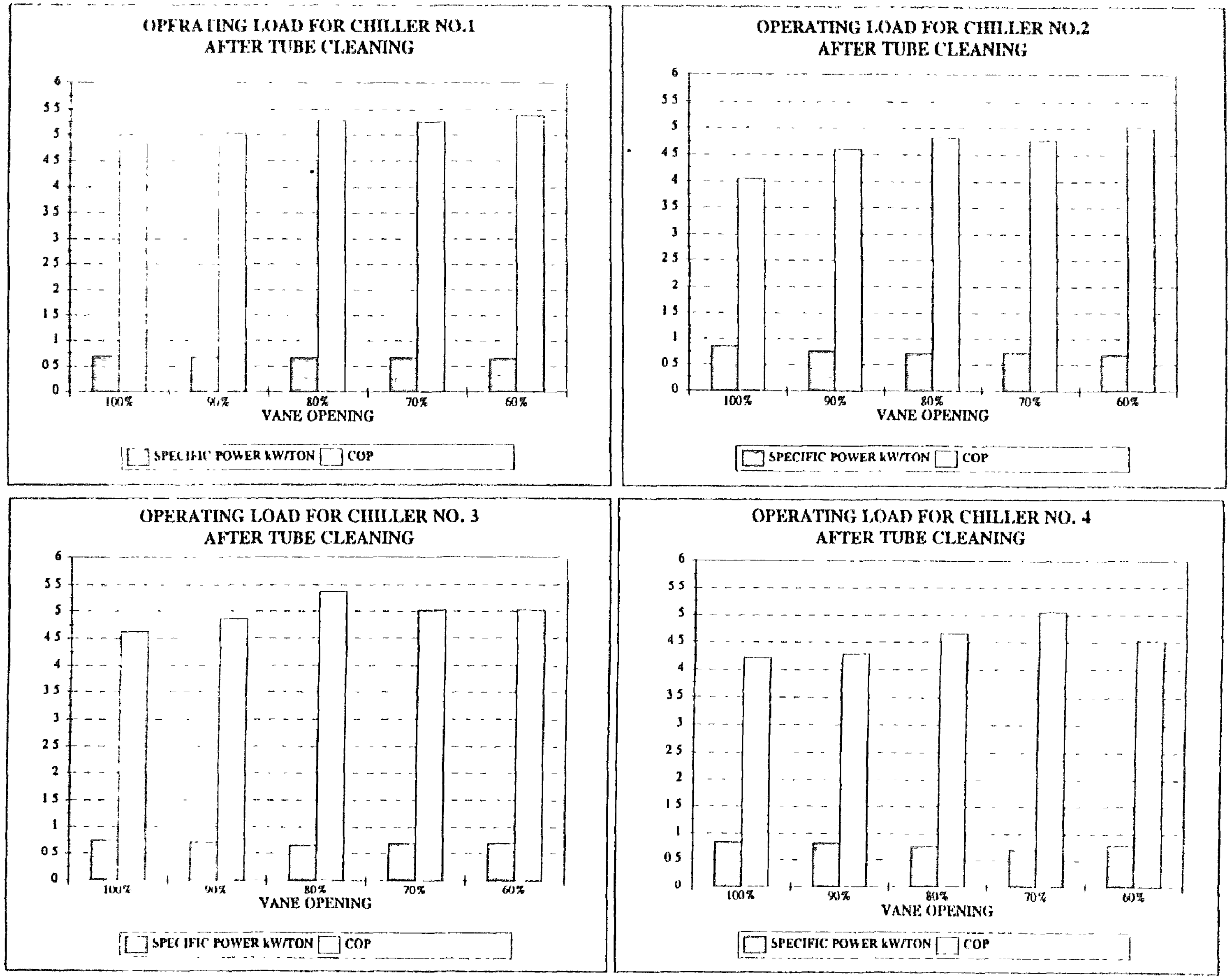

OPERATING LOAD FOR CHILLER NO. 1
BEFORE TUBE CLEANING
OPERATING LOAD FOR CHILLER NO.2
BEFORE TUBE CLEANING
OPERATING LOAD FOR CHILLER NO. 3
BEFORE TUBE CLEANING
OPERATING LOAD FOR CHILLER NO.4
BEFORE TUBE CLEANING
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
5.5
6
100%
75%
60%
VANE OPENING
SPECIFIC POWER kW/TON
COP

FIGURE 3.7


OPERATING LOAD FOR CHILLER NO.1 AFTER TUBE CLEANING

OPERATING LOAD FOR CHILLER NO.2 AFTER TUBE CLEANING

OPERATING LOAD FOR CHILLER NO. 3 AFTER TUBE CLEANING

OPERATING LOAD FOR CHILLER NO. 4 AFTER TUBE CLEANING

FIGURE 3.8

Table 3.11. Fan Coil Units (FCUs)

S.No.	Rated capacity	Number
1	1 TR	388
2	1.5 TR	269
3	2 TR	154

The TERI audit team felt that it would be extremely difficult to study the performance of all AHUs in stipulated time of energy audit, hence a sample of AHUs consisting a few AHUs of each model have been selected for measurement. Total filter area was measured and coil face area was calculated. The air flow in individual AHUs was measured with the help of a digital velometer. The supply and return air DB and WB temperatures were also measured to estimate the load on individual AHUs. The findings are tabulated in table below.

Table 3.12. AHU Load Estimation

S No	Area	AHU type	Quantity (cfm)	Pressure drop across the fan (mm of water)	Entering Air			Leaving Air			Load	
					DB° F	WB° F	Enthalpy (Btu/l)b	DB°F	WB° F	Enthalpy (Btu/lb)	Btu/hr	TR
1	Link corridor	AH - 6	6575	17.5	77	71	34.81	65	63.5	28.86	175920	14.6
2	Tower Restaurant	AH - 7	6082	30.1	79.5	70	33.921	62.6	60.8	26.939	191040	15.8
3	Business/Conference	AH - 7	6934	16	76	70.5	34.382	62.5	61	27.079	228000	18.9
4	Tower lobby	AH - 9	11096	23	78	71	34.8	66.5	64.5	29.601	259560	21.5
5	Madira	AH - 6	5427	20	73	66	30.704	60.5	59.0	25.720	121680	10.1
6	Maurya lobby	AH - 7	6965	17.5	75	67.5	31.880	60.3	58.5	25.387	203520	16.9
7	Shopping Centre	AH - 7	7372	17.5	74	70.5	34.4	62.6	60.6	26.799	252000	20.9
8	Bindiya	AH - 6	6328	18.8	76.5	70	33.947	66.1	65	29.984	112800	9.4
9	Pavilion	AH - 11	10320	21.5	71.7	64.7	29.71	61.8	59.7	26.19	163469	13.6
10	Lobby 10HP	AH - 9	8767	25	74.4	67.7	32.05	60.3	58.6	24.45	260380	21.7

An inclined manometer was used to measure the pressure drop across the fan and the AHU motor loading was measured with the help of a tongue tester. The AHU system efficiency which includes motor, transmission and fan operating efficiencies have been worked out. It has been observed that the fans were operating at an efficiency range between 20 to 55%. The details of the efficiency calculation is given below

Table 3.13. AHU Fan Efficiency Estimation

S No	Area	AHU type	Quantity (cfm)	Pressure drop across fan (mm of water)	Motor rating (HP)	Rated current (amps)	Measured current (amps)	System efficiency %	Fan efficiency %
1	Link corridor	AH - 6	6575	17.5	5	7.6	3.8	28.6	35.4
2	Tower Restaurant	AH - 7	6082	30.1	5	7.6	4.5	38.3	47.4
3	Business/Conference	AH - 7	6934	16	7.5	11.0	5.7	17.7	21.9
4	Tower lobby	AH - 9	11096	23	7.5	10.2	6.1	35.4	43.8
5	Madira	AH - 6	5427	20	5	7.6	4.2	24.4	30.3
6	Maurya/lobby	AH - 7	6965	17.5	7.5	11.0	5	21.2	27.5
7	Shopping centre	AH - 7	7372	17.5	7.5	11.0	5.7	20.6	25.5
8	Bindiya	AH - 6	6328	18.8	5	7.6	5	29.7	36.7
9	Pavilion	AH -11	10320	21.5	12.5	17.5	9.2	20.9	25.9
10	Lobby 10HP	AH - 9	8767	25	10	14	4	46.6	57.7

3.3.2 Cooling Towers

Operational parameters for the cooling towers are given in table 3.13. The cooling towers approach was found in the range of 2 to 7°F. Efficiency of cooling towers has been estimated in the range of 45 to 80% as against the design efficiency of 52%. Condenser water flow measurements indicate a flow of 2243 US gpm as against the required flow of 1543 (when three pumps are in operation) and of 1929 US gpm as against the required flow of 1157 US gpm.

Table 3.13. Cooling Tower Measurements

S.No.	Cooling Tower Type	*Water temp (°F)*		*Sump Temp (°F)*	*Approach (°F)*	*Ambient conditions*			*Efficiency (%)*
		Inlet	*Outlet*			*DB (°F)*	*WB (°F)*	*RH (%)*	
1.	Paharpur1	96.4	90.1	90.3	6.32	95	84	63.70	49.6
2.	Paharpur2			90.1	6.14				51
3.	Paharpur3			90.1	6.86				45.3
4.	Voltas			86.1	2.09				83.3

$$\text{Design Efficiency} = \frac{\text{Design cooling tower inlet temp.- Design cooling tower outlet temp.}}{\text{Design cooling tower inlet temp. - Design wet bulb temp.}}$$

$$\textit{Design Efficiency} = \frac{97.5 - 90}{97.5 - 83} = 52\%$$

3.4 Building Load Profile

3.4.1 Calculated Load Profile

3.4.1.1 Computer Simulation of Maurya Sheraton Hotel and Towers

The thermal analysis of Maurya Sheraton Hotel and Towers has been done by simulation. The computer program used for simulation of a building conceptualises the building to consist of a number of convenient zones and it translates the thermal model of the building into a mathematical form. The mathematical equations of the building are then solved repeatedly at small time intervals (less than one hour) for a user specified period of upto one year. The mathematical representation of the building is a thermal network with non-linear temperature dependent controls. The mathematical solution technique uses a combination of forward finite difference, Jacobean iteration and constrained optimization.

The basic purpose for which simulation has been done are as follows.

1. To determine the heating/cooling load of the building and then compare the results

with loads for which the existing air conditioning plant has been designed.

2. To determine change in heating/cooling loads of building by changing the construction specifications e.g. single glazing instead of double, insulated/non-insulated roof etc.

3.4.1.2 *Inputs for Simulation*

Meteorological Input. The meteorological data for New Delhi has been used for simulation.

Building Input. It is necessary for the purpose of simulation to divide the building into a number of zones. The procedure of zoning involves grouping areas of similar temperatures together while preserving surface areas, aspects and contained volume and thus heat conduction, heat capacity and dominant spatial relationships.

In conformity with above requirements, the Maurya Sheraton Hotel and Towers has been simulated as Maurya Hotel and Maurya Towers. The Maurya hotel was divided into 4 zones - basement, ground floor,upper 1 and upper 2. The upper 1 zone comprises of 4 guest floors and upper 2 comprises of remaining 2 guest floors. The basement and ground floor are synonymous to the area they constitute.

The window area has been calculated for each zone and has been distributed evenly over respective surfaces for each zone. All windows are assumed to be double glazed. Internal loads have been calculated for projected occupancy and lighting/equipment load for each zone.The HVAC set point for each zone has been assumed to be 22°C. The simulation has been run for June 27 (the day for which measurements were taken for air conditioning load calculations) to compare the results of simulated and measured data.

The Maurya Towers has been divided into three zones- basement, ground and upper (constituted by guest floors). The methodology adopted for simulation of Maurya Towers is similar to that of Maurya Hotels. Combined loads for Maurya Hotel and Towers have also been calculated and plotted.

Reiteration has been done with single glazing and non-insulated roof for the Hotel and Towers to determine the change in cooling load profile for the changed construction parameters.

3.4.2 *Comparison between measured and calculated load*

Chilled water header temperature and entering chilled water temperatures were measured at 2 hour interval on 27th June and the building load profile was developed for the same day (Figure 3.9). Computer simulation of the building was done for the same day for which the building load profile was developed (Figure 3.10). The measured load profile shows

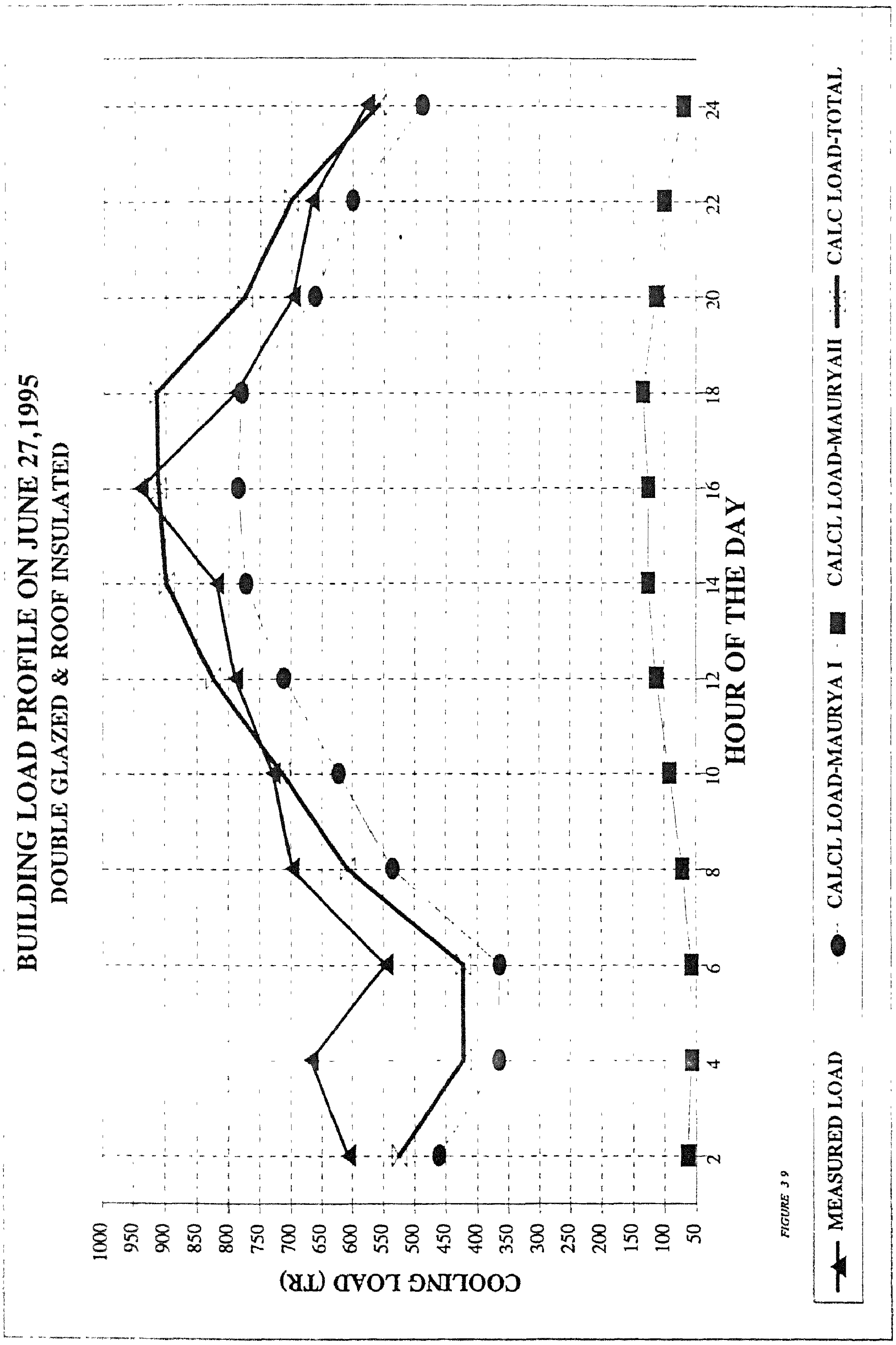

BUILDING LOAD PROFILE ON JUNE 27,1995
DOUBLE GLAZED & ROOF INSULATED
COOLING LOAD (TR)
1000
950
900
850
800
750
700
650
600
550
500
450
400
350
300
250
200
150
100
50
2
4
6
8
10
12
14
16
18
20
22
24
HOUR OF THE DAY
MEASURED LOAD
CALCL LOAD-MAURYA I
CALCL LOAD-MAURYAII
CALC LOAD-TOTAL

FIGURE 3 9

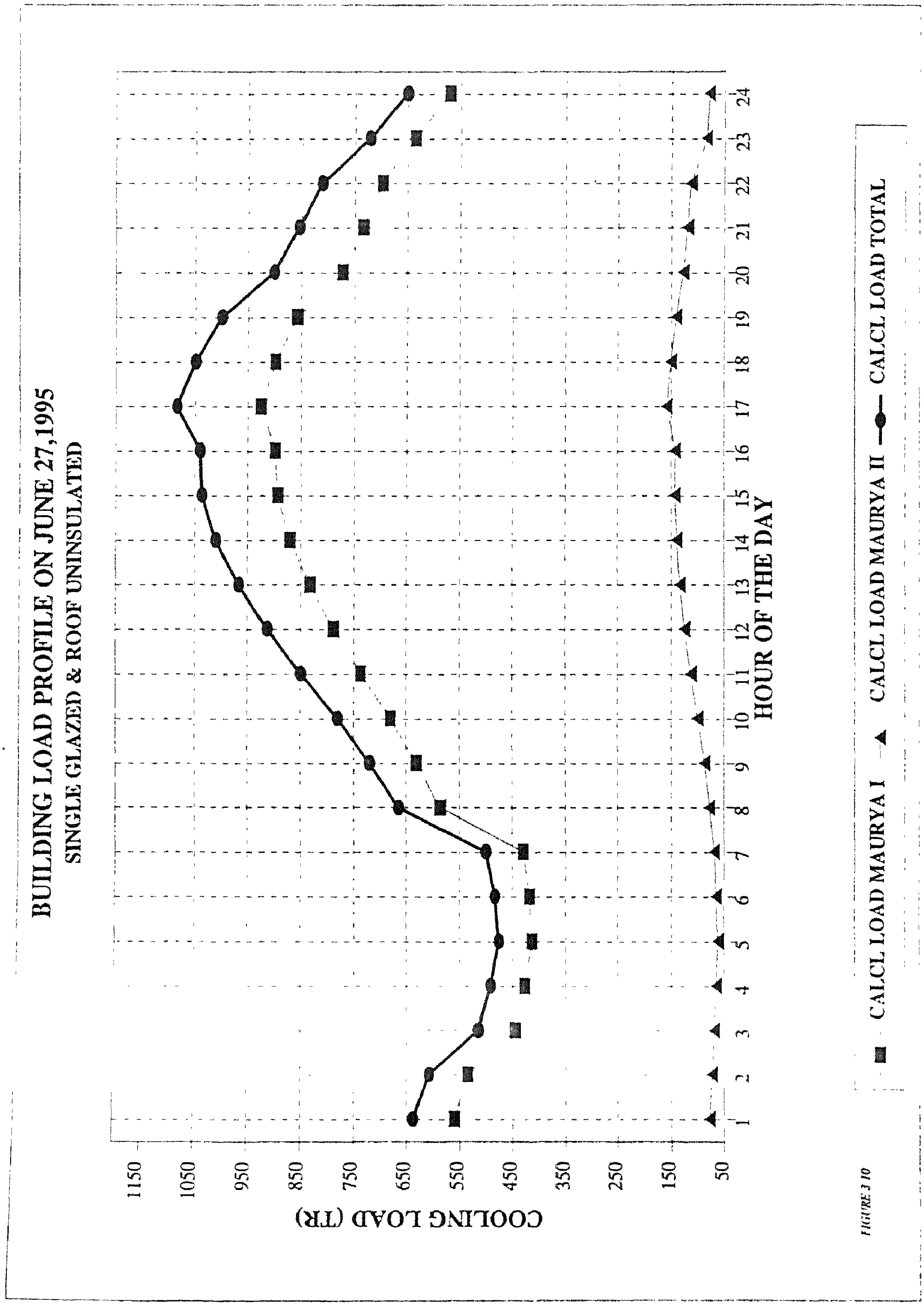
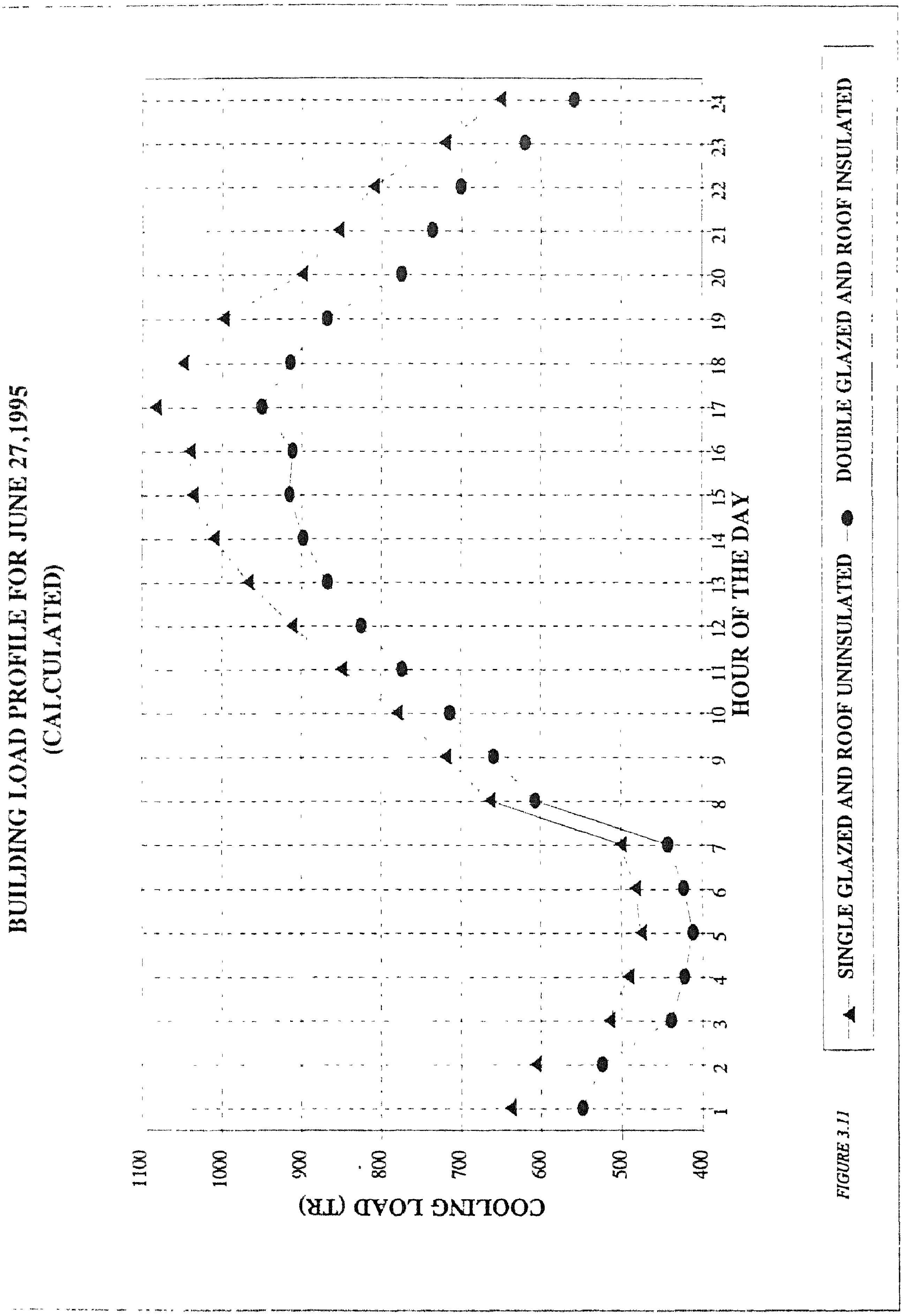

BUILDING LOAD PROFILE ON JUNE 27,1995
SINGLE GLAZED & ROOF UNINSULATED
COOLING LOAD (TR)
1150
1050
950
850
750
650
550
450
350
250
150
50
HOUR OF THE DAY
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
■ CALCL LOAD MAURYA I
▲ CALCL LOAD MAURYA II
● CALCL LOAD TOTAL

FIGURE 3.10



BUILDING LOAD PROFILE FOR JUNE 27,1995
(CALCULATED)

FIGURE 3.11

that there is an increase in building load from midnight to 4 a.m. The increase in air-conditioning load between midnight and 4 a.m. in the morning could be due to increase in human traffic from international flights and then it decreases till 6 a.m. After that it slowly starts increasing and around 4 pm it achieves the peak after which it keeps decreasing till midnight. The simulated building load profile however showed a decrease in load from midnight to 5 am and then increase from 5 am to 5 pm when it peaks. There is then a steady decrease from 5 pm to 5 am in the morning. The maximum measured building load on 27th June was around 940 TR at 4 pm and the minimum was approximately 550 TR at midnight.

The simulated profile shows a maximum peak of 950 TR at 5 pm and a minimum of 412 TR at 5 am. The simulated profile gave the building load of 558 TR at midnight. Load breakup of Maurya I and Maurya II has also been plotted.

(Figure 3.11) gives the 27th June building load profile with single glazing and non-insulated roof. (Figure 3.11) also gives the comparison between simulated load profile for the existing building i.e. with double glazing and insulated roof, and building with single glazing and non-insulated roof. It shows that use of roof insulation and double glazing reduces the building load by about 10-16%.

A sample building input file used for simulation has been enclosed (Annexure 1.1). It can be seen from the input files that the acceptable values of several parameters like air change rate, heat transfer coefficients etc. have been assumed.

3.6 Energy Conservation Opportunities

3.6.1 Optimize the chiller bank operation

From the estimated daily load profile of the month of June, it is apparent that the building cooling load fluctuates in the range of 500 to 900 TR. The hourly variation shows that the minimum load is approximately 500 TR and the maximum load is approximately 950 TR which lasts for very short time (less than one hour). From the daily load profile it can also be observed that for most of the time the building load remains in the load range of 600 TR - 900 TR. Load range and the no. of hours for which the building cooling load remains in that range are given in table 3.14 below.

Table 3.14. Daily distribution of the building load

Load Range (TR)	*No of Hours (hrs)*
500 - 600	4.5
600 - 700	7
700 - 800	7
800 - 900	4.5
900 - 1000	1

The chiller performance data show that they generally operate at maximum efficiency when they are loaded in the range of 70 ~ 80% of their full load capacity. The TERI audit team felt that with the building load profile and the chiller efficiency data, a schedule of chiller operation can be developed in order to maximize the chiller bank operation.

When the building cooling load is in the range of 500 TR - 600 TR, and if two chillers are in operation the minimum cooling they have to produce is 250 TR and maximum 300 TR each. But the chiller performance data show that at 100% loading one chiller can produce only 280 TR. Therefore, two chillers will not be sufficient to produce required cooling and also chiller at full load operates at less efficiency than at part load. Hence three chillers have to operated. At 500 TR building load if two chillers are in operation they have to produce 250 TR each and from (Figure 3.12), it can be estimated that they will consume total 340 kW. If three chillers instead of two chillers are in operation they will consume only 330 kW. Likewise when the building load is 700 TR and three chillers are in operation they will consume 468 kW and if four chillers are in operation they will consume only 460 kW. Comparison of various combination of chillers in operation at different building loads, their input kW and vane openings are listed in table 3.15.

Table 3.15. Comparison of different chiller bank operation

Building Load (TR)	*Two chillers in operation*		*Three chillers in operation*		*Four chillers in operation*	
	Total input (kW)	*Vane opening (%)*	*Total input (kW)*	*Vane opening (%)*	*Total input (kW)*	*Vane opening (%)*
500	340	90	330	62	-	-
600	-	-	395	69	-	-
700	-	-	468	83	460	63
800	-	-	547	94	526	69
900	-	-	635	-	596	80

As it is evident from the above table, it will be economical to run three chillers whenever building load is 500 TR and four chillers whenever building load exceeds 700 TR. Hence a schedule can be developed. Building load profile shows from midnight to 8:00 a.m. the building load is in the range of 500 TR to 700 TR. So three chillers can be kept operation in this period. After 8:00 am load exceeds 700 TR and between 8:00 a.m. to 8:00 p.m. it remains in the range of 700 TR to 950 TR. So at 8:00 a.m. all the four chillers should be made operational and they should be kept operational till 8:00 p.m. At 8:00 p.m. one chiller should be kept off and remaining three will be left operational till midnight. So the final schedule will be as follows

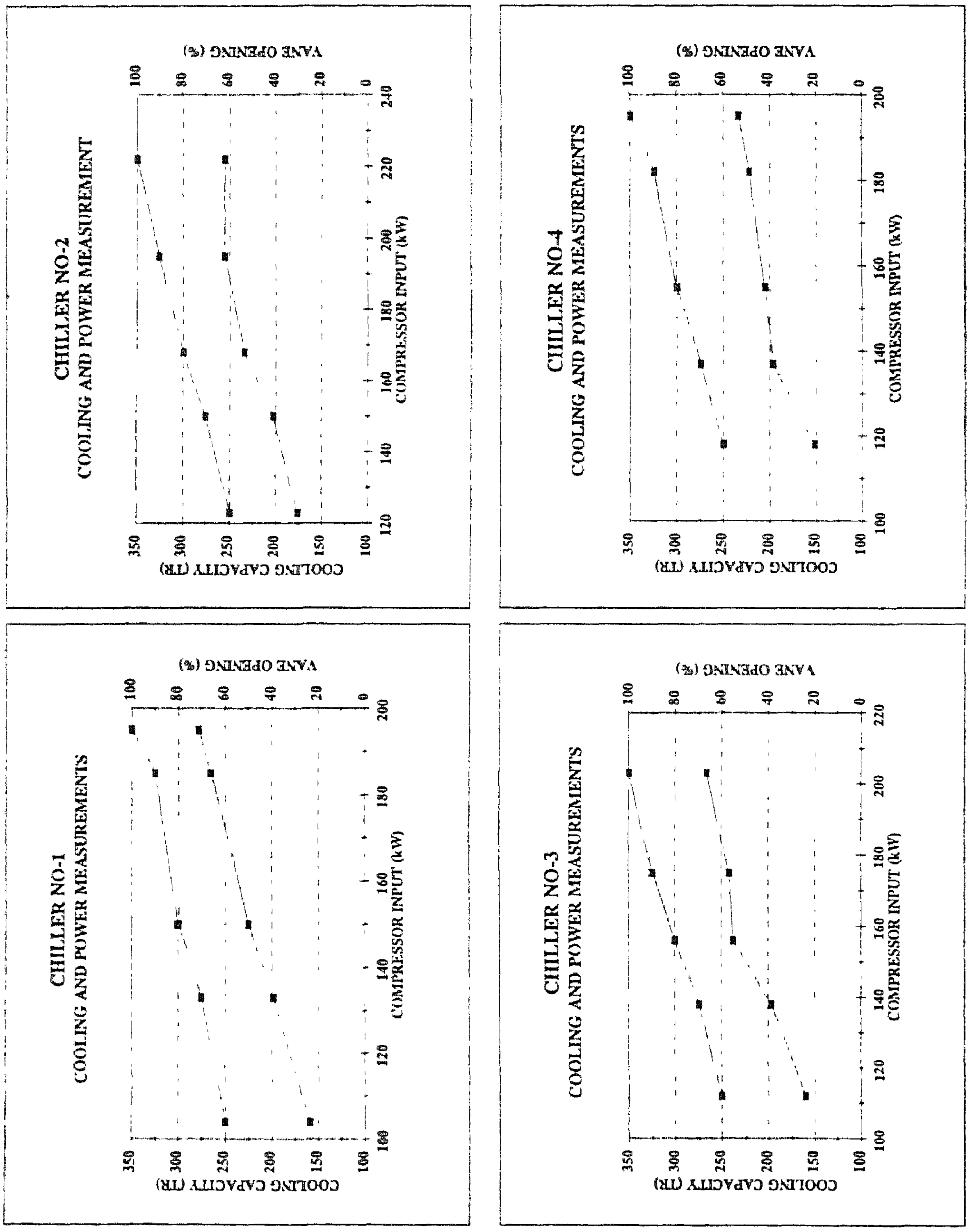

CHILLER NO-1
COOLING AND POWER MEASUREMENTS
COOLING CAPACITY (TR)
350
300
250
200
150
100
VANE OPENING (%)
100
80
60
40
20
0
COMPRESSOR INPUT (kW)
100
120
140
160
180
200
CHILLER NO-2
COOLING AND POWER MEASUREMENT
COOLING CAPACITY (TR)
VANE OPENING (%)
COMPRESSOR INPUT (kW)
120
140
160
180
200
220
240
CHILLER NO-3
COOLING AND POWER MEASUREMENTS
COOLING CAPACITY (TR)
VANE OPENING (%)
COMPRESSOR INPUT (kW)
100
120
140
160
180
200
220
CHILLER NO-4
COOLING AND POWER MEASUREMENTS
COOLING CAPACITY (TR)
VANE OPENING (%)
COMPRESSOR INPUT (kW)
100
120
140
160
180
200

FIGURE 3.12

Table 3.16. Chiller bank operation schedule for the month of June

Duration	No. of chillers to be kept operational
0 - 8 hrs	Three chillers
8 - 20 hrs	Four chillers
20 - 24 hrs	Three chillers

If two chillers are kept operational instead of three chillers in the load range of 500 to 600 TR. There would be an extra consumption of 19.5 × 4.5 = 87.75 kWh daily and if three chillers are kept functioning instead of four chillers in the load range of 700 to 800 TR, the extra consumption would be 14.5 × & = 101.5 kWh and again if three chillers are run instead of four chillers there will be an extra consumption of 30.5 × 4.5 = 137.25 kWh daily (which is the present schedule of chiller bank operation). So with the new operational schedule daily saving which can be achieved would be approx. 327 kWh and the monthly savings would be 9810 kWh and if it assumed that the same savings can be achieved in 10 months in a year. The total annual savings would be approximately = 98,100 kWh or Rs 4.45 lakhs.

3.6.2. Install smaller size impeller to maintain the required flow

The total required chilled water flow is 3596 US gpm (899 US gpm per chiller) and it is circulated in the chilled water circuit with the help of four Becon type L Horizontal split casing pumps of 45 HP each. (Model No - 6L3 - 203 - 152 - 5173/49 × 337). During measurements it has been observed that the flow through all the chillers is maintained even if they are not in operation. The flow is maintained usually with three pumps and rarely with four pumps. The total flow with three pumps has been estimated to be 1640 US gpm and with four pumps 1446 US gpm as against the required flow of 1200 US gpm or 900 US gpm. As mentioned above for most of the time three pumps are kept in operation and they deliver 4960 US gpm or 1640 US gpm per pump which is much more than the required flow of 1200 US gpm per pump. From CHW pump performance curve (figure 3.13) is evident that at 1640 US gpm flow the pump operates at a low efficiency and low head and high BHP. If the existing impeller size of the pump is replaced by just one smaller size of impeller (Model No 6L3 - 203 -152 - s173/49 x 305) pump rating will reduce to 35HP. The pump characteristic curve (Figure 3.13) of the new pump model shows that both at 900 US gpm & 1200 US gpm this pump will operate at better efficiency. The present installed 45 HP pump takes 33.5 kW input while the new 35 HP pump will take 26 kW input. As mentioned earlier pumps are running continuously. Hence assuming that three pumps are running round the clock and for the whole year total saving will be - (33.5 - 26) × 24 × 365 × 3 = 1,97, 100 kWh. At present electricity tariff of Rs 4.13, the total annual saving would be approx Rs. 8,14,023.

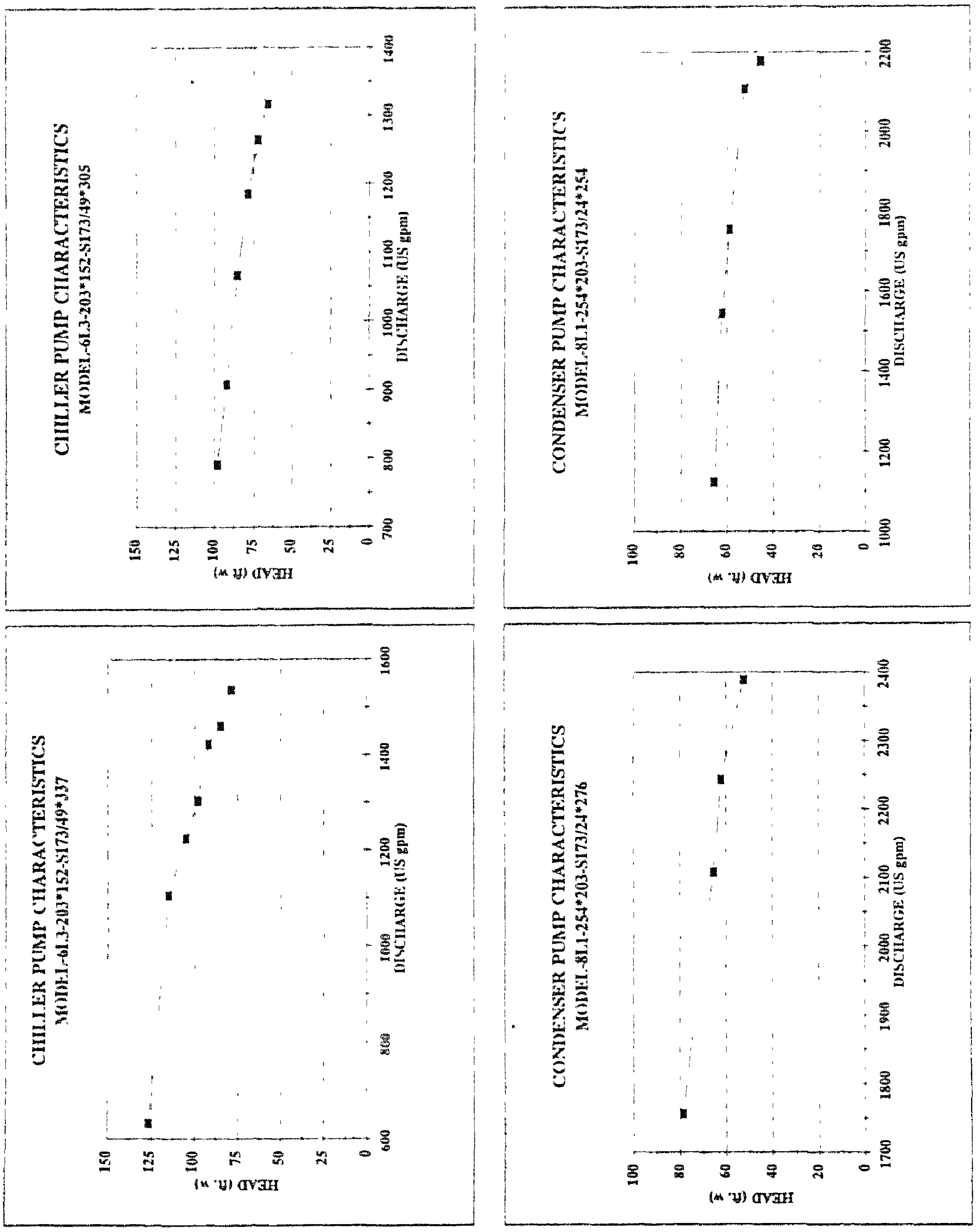

CHILLER PUMP CHARACTERISTICS
MODEL-6L3-203*152-S173/49*305
HEAD (ft w)
150
125
100
75
50
25
0
700
800
900
1000
1100
1200
1300
1400
DISCHARGE (US gpm)
CHILLER PUMP CHARACTERISTICS
MODEL-6L3-203*152-S173/49*337
HEAD (ft. w)
150
125
100
75
50
25
0
600
800
1000
1200
1400
1600
DISCHARGE (US gpm)
CONDENSER PUMP CHARACTERISTICS
MODEL-8L1-254*203-S173/24*254
HEAD (ft. w)
100
80
60
40
20
0
1000
1200
1400
1600
1800
2000
2200
DISCHARGE (US gpm)
CONDENSER PUMP CHARACTERISTICS
MODEL-8L1-254*203-S173/24*276
HEAD (ft. w)
100
80
60
40
20
0
1700
1800
1900
2000
2100
2200
2300
2400
DISCHARGE (US gpm)

FIGURE 3 13

Similarly, the total required condenser water flow is 4628 US gpm which is delivered with the help of four Beacon type 'L' Horizontal split casing pumps (Model No - 8L1 - 254 X 203 - S173/24 × 276). When three pumps are in operation total required flow is 1543 US gpm per pump and when four pumps are in operation the required flow per pump is approx 1157 US gpm. The observed flow during measurement is 2243 US gpm per pump when three pumps are in operation. The operating flow is much more than the required flow. Also from pump characteristic curve (Figure 3.14) it is apparent that the pump is operating at very low efficiency and the discharge point lies outside the curve. This shows that the pumps selection is wrong. If the installed pump impeller size is replaced by just one lower impeller size the pump characteristic curve shows that the pump at 1543 US gpm flow will operates at high efficiency. The presently installed pump which is of 50 HP rating when operates take 37 kW input energy. The new pump with 40 HP rating will take only 30 kW. Hence it is assumed that if the three condenser pumps are running continuously for the whole year, the total savings by replacement of the impeller will approximately

- (37 - 30) × 24 × 365 × 3 = 1,83,960 kWh

- or 183960 × 4.13 = Rs.7,59,750

Hence, by maintaining the required flow in chilled water line and condenser water line with the help of smaller impellers a total annual savings of Rs 15.7 lakhs can be achieved.

CHAPTER 4

Electrical Systems

4.1. Power Distribution System

The Maurya Sheraton hotel receives power supply from New Delhi Municipal Corporation (NDMC) through two H.T. feeders at 11 kV. One H.T. feeder gets power supply from Nehru park and other from Bapu Dham sub-station. The hotel draws power supply through one H.T. feeder and other feeder is kept as standby. In case of power failure from one feeder, the hotel can draw power supply from second feeder.

There are five distribution transformers of 1000 kVA, 11/0.433 kV rating each installed in the sub-station located in the hotel complex. The power supply from H.T. feeder at 11 kV is stepped down to 0.433 kV through these distribution transformers and then fed to different load centers in the hotel. Energy meters have been provided on the secondary (L.T.) side of the distribution transformers and at various locations to monitor electricity consumption. Secure meters have also been provided on the secondary (L.T.) side of each distribution transformer which continuously monitor the load and record all electrical parameters on a half hourly basis.

The electrical load at Maurya Sheraton hotel mainly consists of HVAC, motors, heating and lighting load. The motors are of various sizes ranging from fractional rating to large motors of 212 kW.

Electricity is billed every month based on the energy consumption during the billing period. The Electricity is charged at the rate of Rs. 4.19 per kWh and there is no demand charges in the electricity tariff. The total contract demand of the hotel is 5000 kVA and max. demand goes upto 3500 kVA.

4.2 Power factor

The line current drawn by induction motors, transformers and other inductive devices consists of two components: the magnetizing current and the power producing current. The magnetizing current is required to produce the magnetic flux in the machine. This component of current creates a reactive power component which is measured in kilo-volt-amperes reactive (kVAR). The power producing current is that current which reacts with the magnetic flux to produce the output torque of the machine. This component of current creates the load power requirement measured in kilowatts (kW). The magnetizing current is essential for transferring power through the core of a transformer or across the air gap of an induction motor and lags the voltage by 90°. The total current drawn by the machine is the vector sum of this reactive current and the power producing current. The power factor is defined as the cosine of the angle between the total current and power producing current vectors.

Low power factor leads to poor system efficiency as the high reactive component associated with low power factor gives rise to generating losses throughout the system. An improvement in power factor leads to.

- Reduction of load on transformers and associated distribution equipment.
- Reduction in load losses in transformers, distribution cables and other associated equipments, resulting in a direct saving of kWh power consumption.
- Stabilization of the system voltage.

However, power factor improvement in present case would not result in monetary savings, as the electricity is billed only on the basis of energy consumption and there are no demand charges and low power factor penalty clause in the electricity tariff structure.

4.2.1 *Present power factor scenario*

The electrical load at Maurya Sheraton is fed from five distribution transformers of 1000 kVA each. The hotel has already installed capacitor banks on three out of five transformers to improve the overall power factor of the hotel. A total of 530 kVAR has been installed to improve the power factor for a total connected load of 4555 kVA. The location and size of the capacitor banks installed are given in Table 4.2.1.

Table 4.1. Details of capacitor banks installed

S.No.	Location	*Capacity (kVAR)*
1	EMP-1 (Trf-1)	180
2	ACP-3 (Trf-3)	150
3	ACP-2 (Trf-4)	200
	Total	530

The power factor of loads fed from each transformer is recorded after every two hours from the secure meters installed on the L.T. side of transformers. Since the load on each transformer fluctuates widely, automatic power factor correction relays have been installed on the L.T. side of transformers to maintain a 0.99 lagging power factor at all loads. Automatic power factor correction relay senses the load, voltage and current of the circuit and automatically control the switching on/off of capacitors from the bank, delivering high power factor (at pre-selected level) at all loads.

Various data on power factor was collected from the log book maintained in the engineering department of the hotel to analyse the present scenario and to formulate the future course of action. The data on power factor was collected for the months of August 1994 and January 1995. These two months were particularly selected so as to study the daily variation of power factor when automatic power factor correction relays were functioning and when they were out of order. Discussion with hotel personnel revealed that power factor correction relays have been out of order since October 1994 and presently they are maintaining power factor by manually switching on/off of capacitor banks. Figures 4.1 to 4.8 represent the high and low of daily power factor values for the months of August 1994 and January 1995. It could be seen from the graphs that there was a large variation of power factor value when they were manually switching on/off the capacitor banks. It could be seen from the graphs that the power value was as low as 0.565 and as high as 0.91 in the month of January 1995. Since there is wide fluctuation of loads in the hotel, it would be extremely difficult to switch the capacitors on and off manually in order to keep the overall power factor high at all loads. It is, therefore, recommended to rectify the automatic power factor correction relays installed in the sub-station for better control of power factor.

The power factor of loads from transformer-5 could not be analysed for the same period because secure meter had not been installed on the transformer till that time. Therefore, the data on power factor of loads from transformer-5 was collected for the month of April 1995 and figure 5.9 shows the high and low of daily power factor values of loads from transformer-5. It could be seen from the figure 5.9 that there was large variation of daily power factor depending upon the load on the transformer. It is recommended that capacitor banks should also be installed on transformer-5 to improve power factor to 0.95 at all loads. Discussion with plant personnel revealed that max. load on transformer-5 goes upto 210 kVA and taking the average power factor of 0.84, it was calculated that a total of 70 kVAR should be installed on the transformer-5 with automatic power factor correction relay. The required size of capacitors to be connected, investment required and reduction in demand has been worked out and presented in table 4.2.2.

Table 4.2. Capacitive compensation on transformer - 5

S.No.	Item/Parameter	Value
1.	Max. power of loads from transformer-5 (kW)	210
2	Prevailing average power factor (%)	84
3.	Desired average power factor (%)	95
4	Proposed capacitor value (kVAR)	70
5.	Reduction in demand value (kVA)	29
6.	Investment in capacitor bank (Rs) (@ Rs400/per kVAR	28,000
	Investment in power factor controller (Rs)	
7.	Total investment (Rs)	8,000
8.		36,000

It can be seen from the table that a total of 29 kVA reduction is possible by improving the power factor to 0.95 for the loads fed from transformer-5.

4.3 Electric Motors

The energy audit of the motors installed in the hotel was carried out to study, analyse and identify the potential for energy conservation in motors. In order to evaluate the performance of motors and to see how they are loaded, load tests were conducted on all the available motors equal to and above 18.5 kW (25 H.P) rating as they form major load of the total motor load of the hotel. A total of 12 motors were tested and care was taken to record the peak load taken by the motors to decide the extent of over or underloading. Table 4.3.1 gives the result of motor load tests.

Table 4.3. Motor Loading

S.No.	Drive	*Rated Power (kW)*	*Rated Current (Amps)*	*Measured Current (Amps)*	*Measured Power (kW)*	*Percentage Loading*
1.	Condenser water Pump No.1	37	65	50.4	29.8	74.0
2.	Condenser water Pump No.2	37	65	56.1	33.5	83.29
3.	Condenser water Pump No. 4	37	65	56.3	35.7	89.25
4.	Chiller water Pump No. 2	37	65	53.9	32.6	81.00
5.	Chiller water Pump No. 3	37	65	53.9	32.8	81.55
6.	Chiller water Pump No. 4	37	65	53.8	33.7	83.79
7.	C.T. fan No.1	18.5	33	22.16	10.2	47.41
8.	C.T. fan No.2	18.5	33	21.33	10.6	49.27
9.	C.T. fan No.3	18.5	33	23.83	13.5	62.75
10.	Kitchen Exhaust fan No. 1	15	27	22.2	11.9	69.02
11.	Kitchen Exhaust fan No. 2	15	27	19.7	9.5	54.46
12.	Kitchen Exhaust fan No.3	15	27	15.0	6.6	36.87

4.3.1. Underloaded Motors

It could be seen from the above table that the motor loading varied from 37 percent for Kitchen Exhaust fan no.3 to as high as 89 percent for condenser water pump No.4. To achieve the best design efficiency and power factor values, it is recommended that motor should be loaded in the range of 70-90 percent of the rated power. As could be seen from the table 4.3.1, four motors out of twelve tested were operating at less than 50 percent of their rated capacity. Since the load on these motors would be fairly constant, it can be concluded that these motors are oversized for their respective applications. Significant energy savings could be achieved if proper sized motors are installed in place of these oversized motors. Based on the loading indicated in table 4.3.1 and the discussions with the hotel personnel, recommendations are made to replace oversized motors with motors of appropriate rating.

The following case study for C.T. fan No.1 illustrates the savings that could be achieved by installing a proper sized motor in place of the underloaded one.

4.3.1.1. Case Study of an underloaded motor replacement

Objective. To examine feasibility of using appropriate rating motor in place of 18.5 kW

C.T. fan No.1 and work out the associated energy savings.

Problem. The C.T. fan is driven by a 18.5 kW, 33 Amp squirrel cage induction motor and its loading was measured as 47 percent of the rated power.

Sources.

A. Motor details

Rating	:	18.5 kW
Full load current	:	33 Amps
Full load efficiency	:	0.89
Full load p.f.	:	0.89

B. Existing Operation

Motor loading	:	47.41%
Peak Current	:	22.16 Amps
Input power	:	10.2 kW
Efficiency	:	0.86
Power factor	:	0.63
Load at shaft	:	8.77 kW

C. Proposed motor

Rating	:	11 kW
Full load current	:	20 Amps
Max Loading (for the same load)	:	79.74
Efficiency (at 80% load)	:	0.88
Power factor (at 80% load)	:	0.84

D. Energy Savings

Reduction in input power	:	8.772/0.86 - 8.772/0.88
	:	0.2318 kW
Annual energy saving	:	2030 kWh (@ 8760 hrs/year)
Annual saving in energy charges	:	Rs 8508 (@ Rs. 4.19/kWh)
Investment in new motor	:	Rs 17 000
Salvage value of old motor	:	Rs 7 200
Net investment in replacement	:	Rs 9 800
Simple payback period	:	1.15 years

Similar calculations were performed on all the under-loaded motors of table 5.3.1. Results of such calculations are presented in table 4.3.2 in terms of the size of appropriate motors, annual kWh savings achievable, total investment required and simple payback period of such replacements. It could be seen from the table 4.3.2 that by investing a total sum of Rs 55 000 in replacement cases of five motors, an annual saving of 9800 kWh amounting to Rs 41 000 (@ Rs 4.19/= per unit cost) could be achieved.

Table 4.4. Economics of Replacement of Underloaded Motors

S.No.	Drive	*Existing motor (kW)*	*Proposed motor (kW)*	*Annual energy savings (kWh)*	*Net investment (Rs.)*	*Payback (year)*
1.	C.T. fan no 1	18.5	11	2030	9800	1.15
2.	C.T. fan no 2	18.5	11	2110	9800	1.1
3.	C.T. fan no 3	18.5	15	1343	14200	2.52
4.	Kitchen exhaust fan no 2	15	11	956	11600	2.9
5.	Kitchen exhaust fan no 3	15	7.5	3361	9600	0.7

4.3.2 Energy Efficient Motors

Electricity consumed in motors could be reduced significantly by using energy efficient motors which are now available in our country. Though these motors cost about 40 percent more than the standard motors, their use is justified considering the lower operating cost of these motors. A brief write-up on energy efficient motors is given in **Annexure 1.2.** Economics was worked out for all oversized motors tested for use of energy efficient motors. The five motors which displayed favourable economics, are listed in table 4.3.3 with respective amount of energy saved, investment required and resulting payback period.

Table 4.5. Economics of replacement with Energy Efficient motors

S.No.	Drive	*Loading (%)*	*Existing (kW)*	*Proposed EEM (kW)*	*Annual energy savings (kWh)*	*Net investment (Rs.)*	*Payback Period (year)*
1.	C.T. fan no 1	47.41	18.5	11	4442	15800	0.85
2.	C.T. fan no 2	49.27	18.5	11	4617	15800	0.81
3.	C.T. fan no 3	62.75	18.5	15	5198	22760	1.04
4.	Kitchen exhaust fan no 2	54.46	15	11	4138	18454	1.06
5.	Kitchen exhaust fan no 3	36.87	15	7.5	4477	15600	0.81

POWER FACTOR VARIATION OF LOADS

POWER FACTOR VARIATION OF LOADS
FROM TRF-1

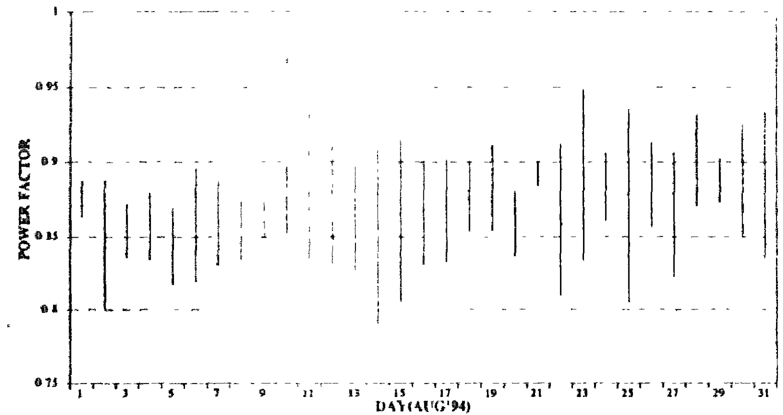


FIGURE 5.1

POWER FACTOR VARIATION OF LOADS
FROM TRF 2

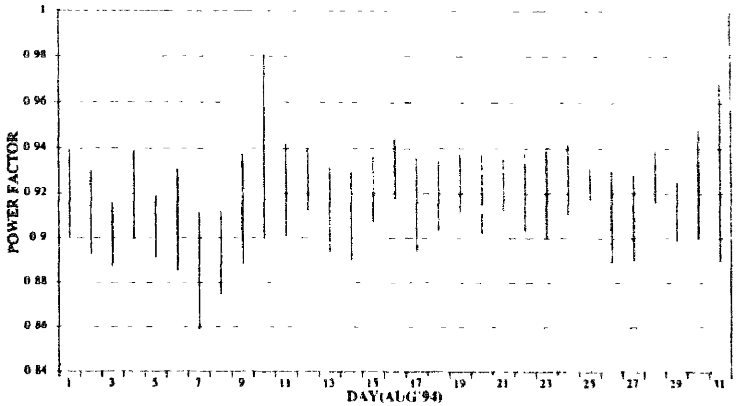


FIGURE 5.2

POWER FACTOR VARIATION OF LOADS
FROM TRF-3

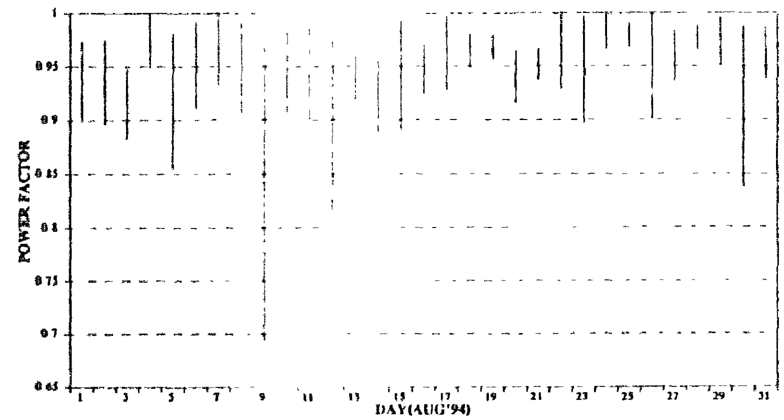


FIGURE 5.3

POWER FACTOR VARIATION OF LOADS
FROM TRF-4

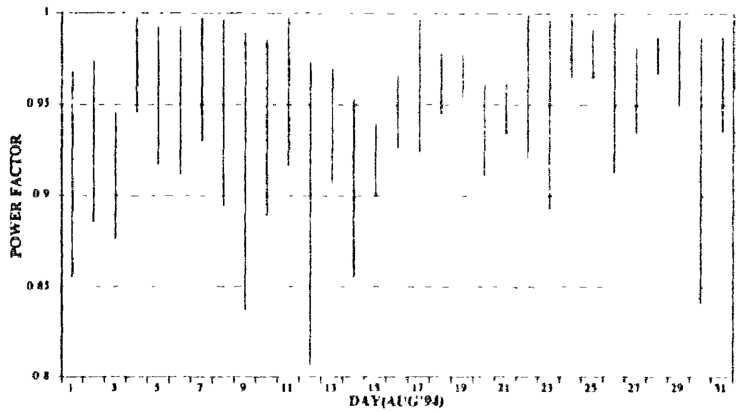


FIGURE 5.4

POWER FACTOR VARIATION OF LOADS

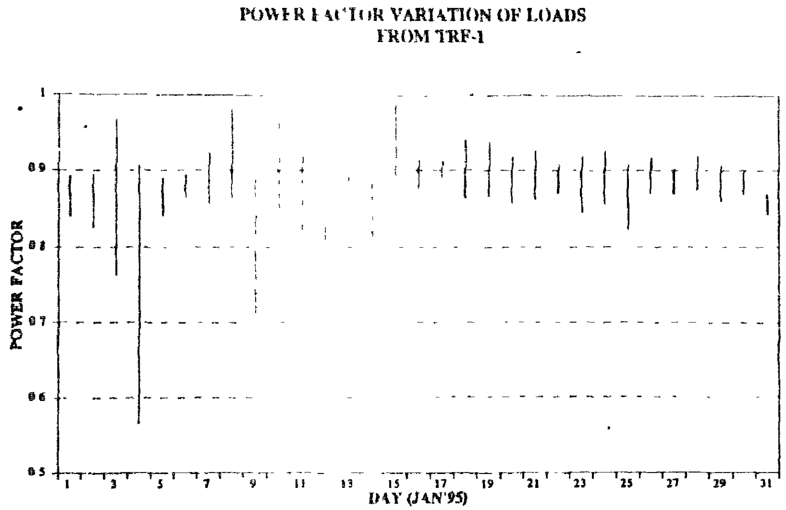


FIGURE 5.5

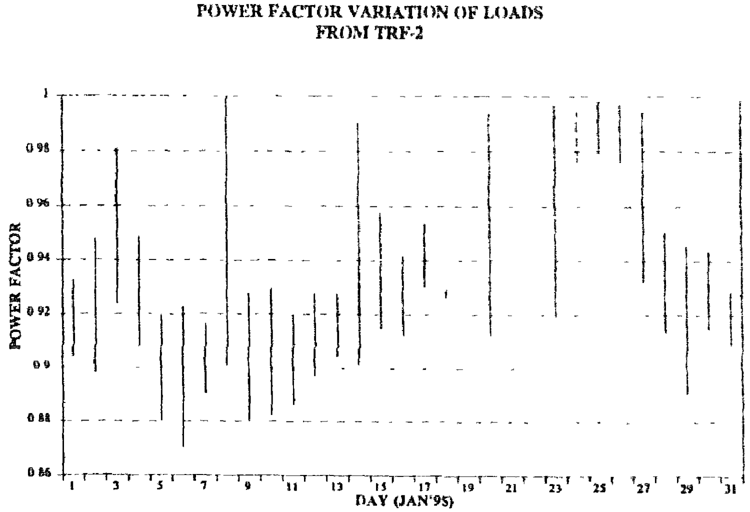


FIGURE 5.6

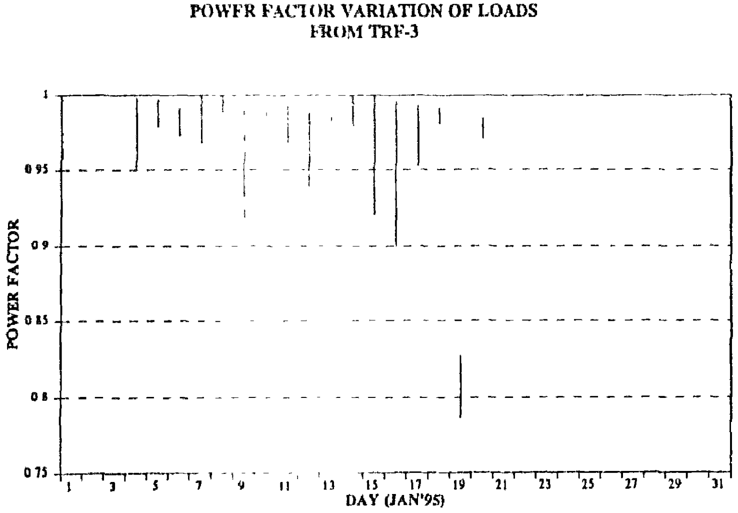


FIGURE 5.7

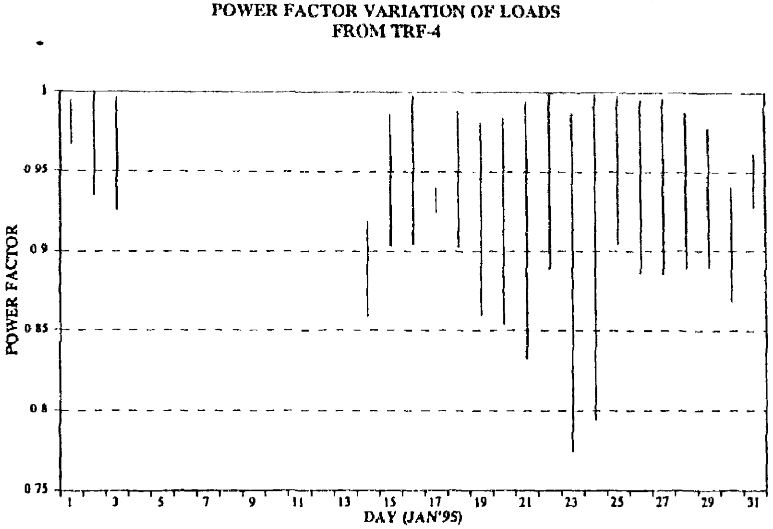
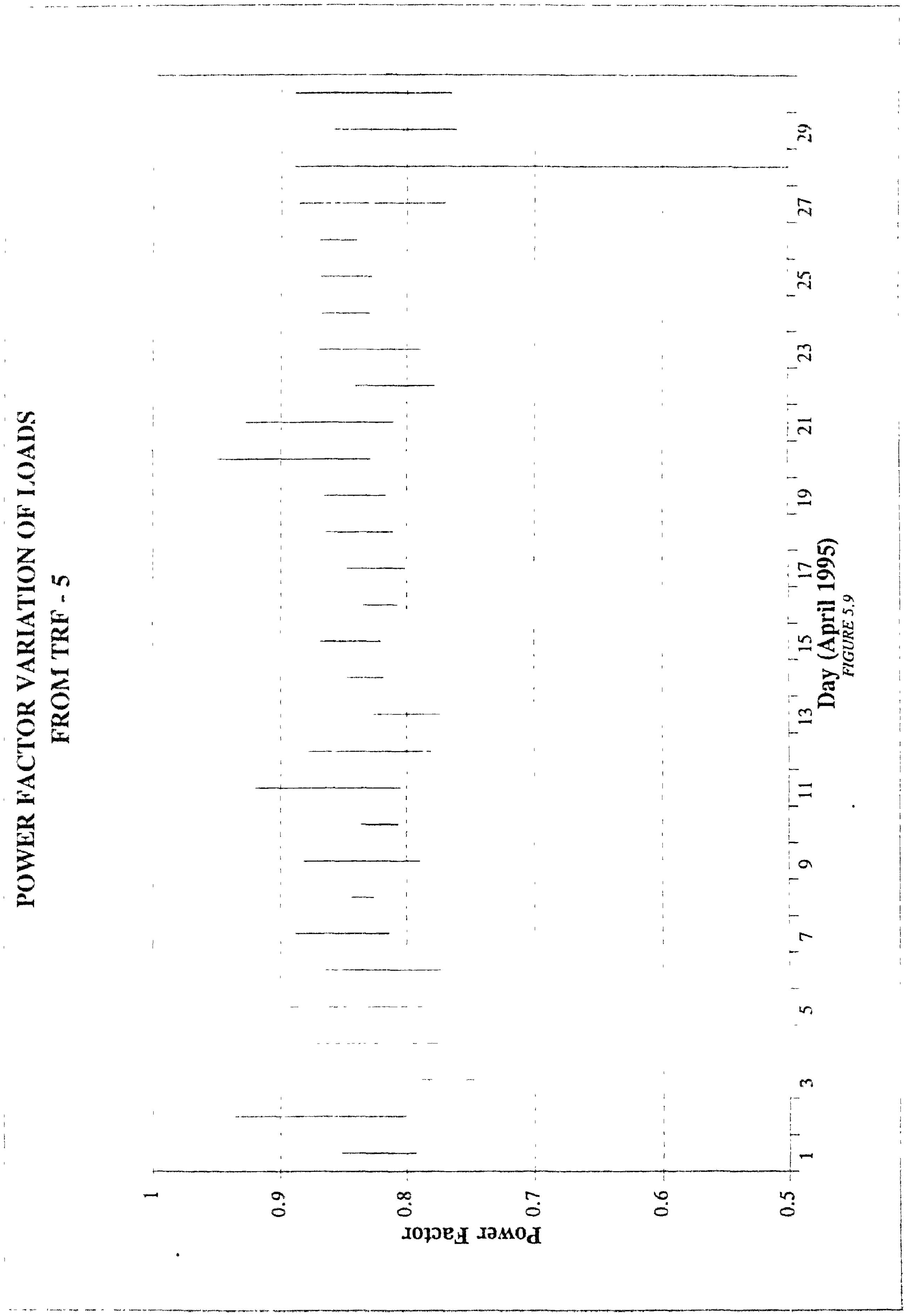


FIGURE 5.8



POWER FACTOR VARIATION OF LOADS FROM TRF - 5

FIGURE 5.9

CHAPTER 5

Boilers

5.1 Details of boilers

There are three oil-fired boilers in the utility area. All the three boilers are of fire-tube type with three pass. Normally one boiler is operated to meet the requirements and the other two boilers are kept as standby. During the time of energy audit, it was found that most of the time, boiler-1 was under operation and therefore the thermal efficiency evaluation was carried out for boiler-1 only.

Table 5.1. Details of boilers

Boiler No.	Make	Year	*Capacity (tph)*	*Design pressure (kg/cm^2)*
1	Nestler	1978	5	8
2	Westerwork	1976	4	8
3	Westerwork	1979	2.5	8

Boiler-1 is a three-pass, horizontal, smoke tube boiler. LDO is used as fuel and when it is not available HSD is used. The oil burner is of the air assisted pressure type. It has two nozzles with low/high firing facility. The boiler-1 was designed to generate 5 tph of steam at 8 kg/cm^2. The boiler operates on forced draught system. The combustion air flow to the boiler is controlled with a damper provided at the FD fan which is regulated with "high/low" firing of the boiler. During high firing, the damper is opened for about 40%, and during low firing it is opened to 10-15%. The operation shifts from high to low firing when the steam pressure approaches 100 psi. The boiler surfaces are provided with glass wool insulation of 3.5" thick while the burner end of the boiler is insulated with Hysil.

The boiler is not equipped with economiser. However, the feedwater, which is a mixture of condensate and the make-up water, comes to the boiler at 95°C. On an average the boiler generates 1700 kg/hr of steam at 7.5 kg/cm^2. The laundry, which is the major consumer of steam, is closed between night 12 'o clock and 6 a.m. Therefore, the boiler is operated for about 17 hours a day. **Figure 5.1** shows the number of hours of operation of boiler-1 during April 1995.

The dissolved solids and the scale forming chemicals in the feedwater are reduced in a resin tank. Intermediate blowdown is adopted to maintain the solids concentration in the boiler water. Blowdown is carried out three times a day and the approximate quantity of blowdown is water 1000 liters. The following sections discuss the methodology adopted for evaluating the boiler performance, various measurements taken, the boiler efficiency and associated heat losses.

5.2 Performance of the boilers

5.2.1 Methodology

The performance of a boiler can be assessed by determining the thermal efficiency of the boiler. The thermal efficiency of a boiler can be evaluated by using **direct or indirect methods**. In the direct method, the efficiency is determined as the ratio of net heat in steam and the total fuel heat input per hour. In the indirect method, first various losses associated with the boiler are calculated and then the boiler efficiency is determined as the difference between the heat input and the sum of the heat losses associated with boiler. The efficiency evaluation by indirect method thus help in quantifying various losses and identifying avoidable losses.

In the following sections, boiler efficiency was evaluated by using both direct and indirect methods. The comparison of boiler efficiency obtained by direct method will help validating the heat loss quantification in the indirect method.

5.2.2 Analysis of boiler efficiency data for April 1995

5.2.2.1. Boiler efficiency by direct method (Boiler-1)

A time series data on the thermal efficiency of boiler-1 by direct method evaluated for April 1995 and the corresponding boiler load are given in **table 5.2**. The average boiler efficiency was computed to be 73% which varied between 54.8% and 87.2%. The average boiler load was found to be 33.2%. The variation of thermal efficiency and the boiler load are shown in **figure 5.2**.

Table 5.2. Performance of boiler-1

S.No	Steam generation (kg)	LDO consumption (lit)	Hours of operation/day	Thermal efficiency (%)	Boiler loading (%)
1	28533	2326	18.1	69.9	32
2	28910	2483	19.0	66.3	30
3	26550	2161	18.3	70.0	29
4	28832	2985	20.9	55.0	28
5	27590	2870	16.6	54.8	33
6	28480	2056	17.5	78.9	33
7	28716	2189	17.9	74.7	32
8	28591	2374	16.6	68.6	34
9	26704	2086	16.0	72.9	33
10	28266	2175	17.0	74.0	33
11	27162	1928	15.1	80.3	36
12	27135	2100	17.3	73.6	31
13	27013	1944	16.8	79.2	32
14	27524	2474	16.5	63.4	33
15	26679	2585	15.9	58.8	34
16	26985	2003	17.2	76.8	31
17	28828	2227	18.4	73.8	31
18	28337	2336	18.5	69.1	31
19	28374	1855	17.9	87.2	32
20	28252	2104	16.4	76.5	35
21	28799	2100	12.5	78.1	46
22	28930	2224	16.8	74.1	34
23	27858	2086	16.7	76.1	33
24	29652	2128	18.4	79.4	32
25	26827	1865	15.9	82.0	34
26	26964	2152	15.7	71.4	34
27	26847	2201	16.1	69.5	33
28	27115	2002	14.8	77.2	37
29	28067	2118	15.9	75.5	35
30	28418	1928	16.8	84.0	34

Data such as fuel consumption, steam generation, average steam pressure and feedwater temperature for a representative day (9th May 1995) were collected from the log-books. The steps for computing the thermal efficiency computation by direct method are given below.

Steam generation = 1786 kg/hr
Steam pressure = 6.5 kg/cm^2
Enthalpy of steam = 659 kcal/kg
Feedwater temperature = 92°C
Enthalpy of feedwater = 92 kcal/kg
Net heat added per kg of steam = 567 kcal/kg
Total heat output = 1013267 kcal/hr
Fuel consumption = 126 lit/hr

= 120 kg/hr

Total heat input = 1251841 kcal/kg

Thermal efficiency by direct method = 80.9%

5.2.2.2. Boiler efficiency by indirect method (Boiler-1)

To arrive at the thermal efficiency of the boiler by indirect method, the heat input and various heat losses associated with the boiler system were computed. The following parameters were monitored to compute the thermal efficiency of boiler by indirect method. The operating parameters required to evaluate the thermal efficiency of boiler-1 measured during the audit are given in **table 5.3.**

- Flue gas analysis
- Flue gas temperature
- Structural heat loss
- Ambient conditions
- Water quality
- Feedwater temperature

Table 5.3. Operating parameters

Parameter	*Measured value*
Flue gas temperature	230°C
Oxygen content of flue gas	8.9 %
CO content of flue gas	185 ppm
Wet bulb temperature	27°C
Dry bulb temperature	30°C
Feed water temperature	95°C

5.2.3 *Heat balance of boiler-1*

5.2.3.1. Heat input

LDO is used as the fuel in the boiler. The average fuel firing rate is 126 liters per hour (120 kg/hr). The gross calorific value of LDO is 10,450 kcal/kg. The ultimate analysis of LDO used in the heat balance computations is given in **table 5.4.** The total heat input to the boiler was arrived at by multiplying the fuel consumption rate with the gross calorific value of the fuel.

Table 5.4. Ultimate analysis of LDO

Component	*Percentage*
Carbon	84.6
Hydrogen	11.9
Sulphur	2.5
Oxygen	0.5
Moisture	0.5

5.2.4 Heat losses

As a part of efficiency evaluation by indirect method, a detailed heat balance was carried out which is enclosed in **annexure 1.3**. The various heat losses associated with the boiler which are considered for the heat balance are given below.

(i) Flue gas loss
- Dry flue gas loss
- Hydrogen in fuel
- Moisture in fuel
- Moisture in air

(ii) Heat loss due to CO in flue gas
(iv) Heat loss due to blowdown
(v) Structural heat loss

The summary of the results of the heat balance is given in **table 5.5**. As can be seen from the table, the total heat loss associated with boiler-1 was 19.1% of the total heat input. The thermal efficiency of the boiler was found to be 80.9%. A pie-chart showing various heat losses associated with the boiler and the thermal efficiency is given in **figure 5.3**.

Table 5.5. Heat balance of the boiler-1

Type of heat loss	*Percentage*
Flue gas loss	17.8
Heat loss due to CO in flue gas	0.1
Heat loss due to blowdown	0.7
Structural heat loss	0.5
Total heat loss	19.1
Thermal efficiency of boiler	80.9

5.3 Problem areas and potential for energy conservation

5.3.1. Excess air optimisation

The boiler-1 is operating at a high excess air level. The present excess air level is 69% during low firing as against the optimum level of 40%. The combustion air flow to boiler-1 is controlled with respect to high/low firing by regulating a damper provided on the FD blower. The boiler operates mostly in low firing condition. The combustion air flow to the boiler can be further reduced to the desired level by slightly reducing the damper opening. The required position of the damper can be obtained when the corresponding CO_2 level in the flue gas is attained. The desired CO_2 level in the flue gas for 40% excess air level is 10.9%. Presently the boiler is operating at a CO_2 level of 9%. By optimising the excess air level, the boiler efficiency will be improved by about 1.5% This corresponds to an annual saving of 13.2 KL of LDO and Rs 90,000.

Figure 5.1 HOURS OF OPERATION - BOILER-1

(April 1995)

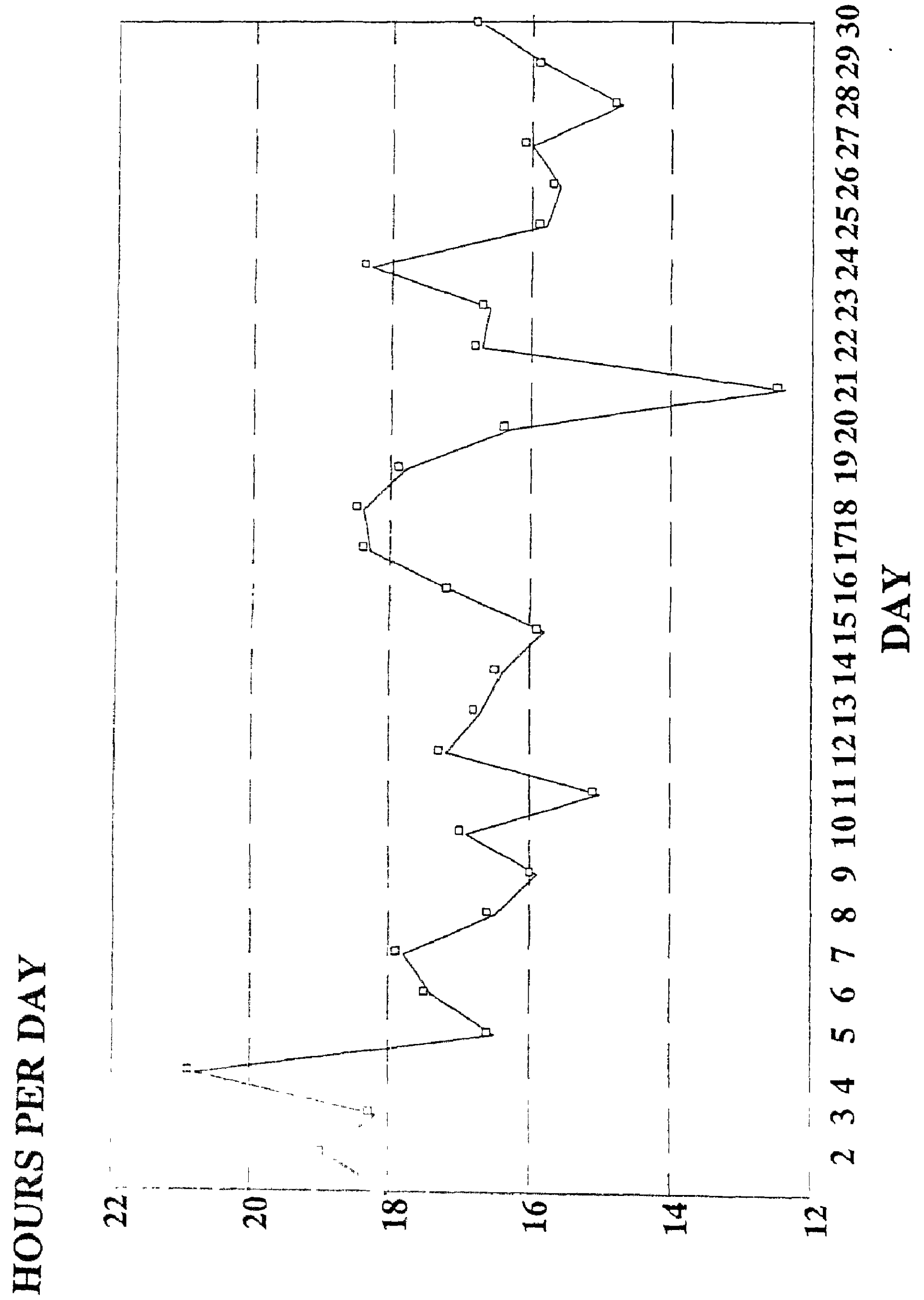
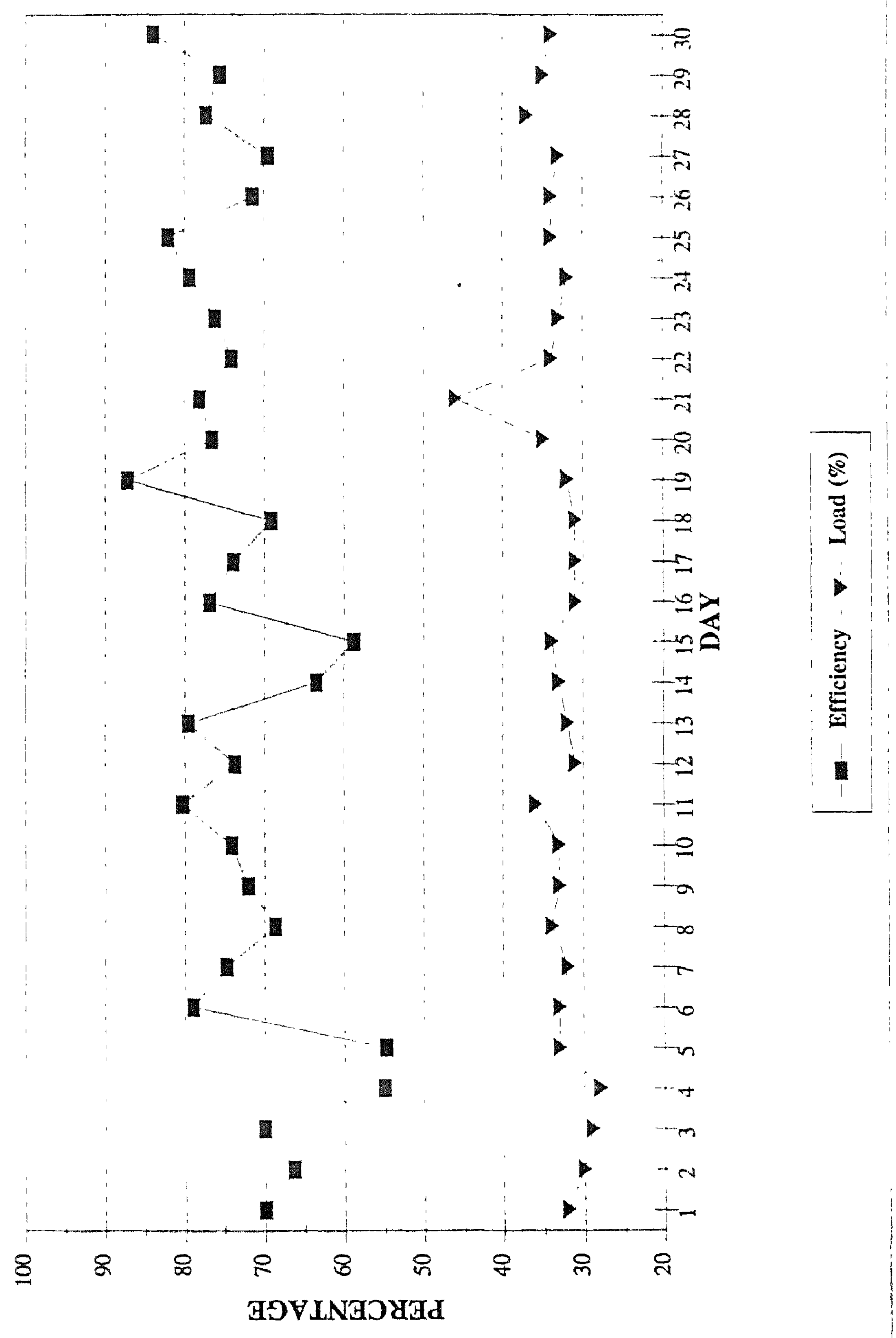


FIGURE 5.2 PERFORMANCE OF BOILER-1
(EFFICIENCY BY DIRECT METHOD)



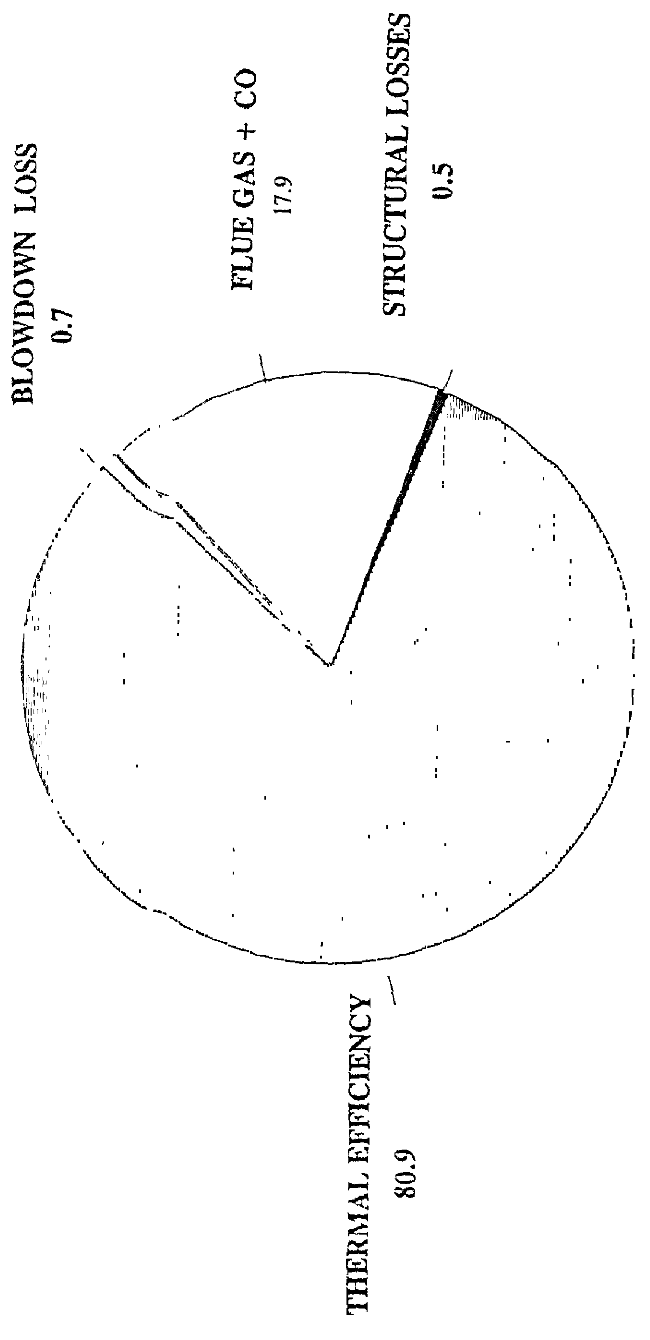


Figure 5.3 HEAT BALANCE OF BOILER -1

CHAPTER 6

Steam Network

6.1 Introduction

A detailed study of the steam network was carried out to evaluate the operating performance of various systems in use and to identify avoidable losses, if any. The study of the steam network covers the following aspects.

- Steam demand
- Steam utilisation
- Steam supply and distribution
- Condensate recovery
- Flash steam recovery

6.2 Steam demand

The total steam demand of the hotel is 28 tonnes per day (tpd). The typical daily steam demand figures for the month of April 1995, as collected from the boiler log-book, are given in **table 6.1**. The graphical presentation of the same is shown in **figure 6.1**. It is evident from the figure that the steam demand of the hotel fluctuates in a narrow range between 27 and 29 tpd. The details of steam consumption, analysed for April 1995 are given in **table 6.1**.

Table 6.1. Steam consumption data for April 1995

	Steam consumption	
	tpd	*tph**
Average	27.9	1.7
Minimum	26.5	1.4
Maximum	29.6	2.3

* tph is tonnes per hour

Absorption chillers, which also consume steam, are not in operation for quite sometime and hence the steam demand figures indicated here do not include the steam consumption by the chillers. The various steam using equipment in the hotel and their steam consumption details are given in the following sections.

6.3 Steam utilisation

Steam from boiler house is supplied through mains to different areas of the hotel complex which are listed below.

(i) Laundry

(ii) Main kitchen

(iii) Health club
(iv) Absorption chillers

6.3.1 Laundry section

Laundry is the largest consumer of steam, accounting for about 80% of the total steam generation. In this section, steam is used at two different pressures viz, 7.5 kg/cm^2 and 4.5 kg/cm^2. The steam required at 4.5 kg/cm^2 is obtained by reducing a fraction of the laundry steam from 7.5 kg/cm^2 in a pressure reducing valve (PRV-1) located at the laundry house. The various steam consuming equipments in the laundry are listed below. The data pertaining to the design & operation of the equipments, and observations made during the field visits are outlined in the following sections.

(a) Washing machines
(b) Dryers
(c) Hot press
(d) Calendar machine
(e) Dry cleaning machine

Washing machines, dryers and calendars use steam at 7.5 kg/cm^2, whereas steam press, hot head press and dry cleaning machine use steam at 4.5 kg/cm^2.

6.3.1.1 Washing machines

The laundry operations begin with washing of cloths using high pressure steam. There are four washing machines in the laundry house. Steam at 7.5 kg/cm^2 is used directly in the washing machines. The hot effluent generated during washing is drained out.

6.3.1.2 Dryers

Washing is followed by drying of the washed wet material. There are four dryers in the laundry. Out of the four, the dryer procured from American Dryer Corporation (ADC) has been installed recently. Steam at a pressure of 7.5 kg/cm^2 is used in all the dryers. The function of steam for the dryer is to heat the incoming dry air in a finned-tube heat exchanger, which is located on the top of the dryer. The hot dry air from the heat exchanger when come in contact with wet cloths, for a preset time, removes the moisture completely. About 45 minutes is required to complete the drying process, once the wet material is loaded into the dryers.

After drying, the hot moist air at 60-80°C, leaves the dryers to the exhaust air duct. The flow of air through the heat exchanger, into the dryer and then finally to the exhaust air duct is accomplished by an induced draft fan provided at the bottom of the dryer. Fresh-air duct openings are provided in the laundry house, close to the dryers, to supply dry clean air to the dryers. The condensate from the heat exchangers is collected and returned to the feedwater tank by a Spirax Ogden automatic pump.

The bulk of the heat supplied to the dryer escapes through hot exhaust air and therefore, recovery of this heat for re-use in the dryer generally offers scope for energy conservation. The various heat recovery options available are.

(1) Recirculation of exhaust air stream to the dryer

(2) Waste heat recovery: Heat in the exhaust air stream can be recovered and used for preheating the incoming supply air. The various options available for heat recovery are (i) Heat wheel and (ii) Heat pipe heat exchanger.

The economic viability of the suggested measures in the present context depends entirely on the amount of heat available in the exhaust air, which is reflected by the exhaust air temperature at the dryer outlet.

With a view to explore the various options available for energy conservation, the energy audit team has measured the exhaust air temperature at the dryer outlet and found to be varying between 65-80°C. A detailed assessment of energy saving potential, using the data collected, indicated that the exhaust air temperature is less than the economic temperature range (economic temperature range of exhaust air is above 90°C) and hence the options considered for energy conservation found to be economically unattractive with very high payback periods.

In-house experiments had also been carried out by the plant personnel to reduce the steam consumption in the dryers. As part of such activity, partial/complete recycle of hot moist air from the dryer exit was tried out for utilising waste heat in the exhaust air. However, the same could not be adopted to the present system due to various problems envisaged during this time. The observations made by the plant personnel and the energy audit team pertaining to the experiments carried out are.

(i) the exhaust air has very high moisture content and therefore, has led to an extended drying period beyond 45 minutes.

(ii) the fine fibrous material separated from cloths during mixing of cloths with air, caused plugging problems effecting the flow of air.

(iii) reduction in steam consumption was not significant due to prevailing low exit air temperature.

6.3.1.3 Calendars

Calendars are metallic hollow rollers which are steam heated. Steam at 7.5 kg/cm^2 is used for heating the rollers. The wet material is allowed to pass over the rollers for drying. It was observed that the moisture separated from the wet material in this section is allowed to escape into the atmosphere. The condensate from the calendars is collected and returned to the feedwater tank using a Spirax Ogden pump.

6.3.1.4 Hot press

The two types of hot press employed in the laundry are.

a. Steam press

b. Hot head press

Both types of press use steam at 4.5 kg/cm^2. Steam is reduced from 7.5 kg/cm^2 to 4.5 kg/cm^2 in a pressure reducing valve (PRV-1), which is located in the laundry house. The numbers of the hot head press and the steam press are given in **table 6.4**.

Table 6.2. Number of hot head and steam press

Size of press	Hot head press	Steam press
Big	3	2
Medium	1	1
Small	2	1

It was observed that the non-working surfaces of the press (i.e. top surface) are not insulated. The skin temperature of the bare surfaces were measured and found to be near the steam temperature. This shows that the radiative and structural heat losses from the surfaces are high. With a view to estimate the surface loss, measurements were taken using a portable heat flux meter. Typical heat loss values measured range between 250 to 480 Btu/ft^2-hr. The total surface heat loss from all the press is estimated to be 850 kcal/hr which is equivalent to a loss of 2000 kg per year of steam at 4.5 kg/cm^2. It is recommended that the bare, non-working metallic surfaces be insulated with glass wool to minimise the surface heat loss. The condensate recovered from the press are collected and returned to the feedwater tank.

6.3.1.5 Dry cleaning machine

There is one dry cleaning machine in the laundry house which uses a fraction of the laundry steam at 4.5 kg/cm^2. The steam is used for distillation of the organic solvent. Steam consumption in the dry cleaning machine is not significant as the machine is used for only few hours a day. The condensate collected from the machine is returned to the feedwater tank.

6.3.2 *Main kitchen*

Main kitchen consumes about 15% of the total steam at 2.5 kg/cm^2. This is obtained by reducing the steam from 7.5 kg/cm^2 in a pressure reducing valve (PRV-2). Majority of steam in the kitchen is used for indirect heating. The condensate is collected and returned to the feedwater tank.

6.3.3 *Health club*

In health club, steam is used at 1.5 kg/cm^2 by reducing the 7.5 kg/cm^2 steam in a pressure reducing valve (PRV-3). Steam is directly used in the health club. The steam consumption of the health club is not significant and represents only 5% of the total steam generation.

6.4 Steam supply and distribution

Steam at 7.5 kg/cm^2 from the boiler house is supplied through mains to different areas of the hotel complex . As discussed in the previous sections, steam is required at four different pressure levels for the hotel complex. A list of the steam using equipment/locations and the desired steam pressures is given in **table 6.3**. A block diagram showing the supply and distribution of steam is given in **figure 6.2**.

Table 6.3. Location and steam pressures used

S. No	Location	Steam pressure (kg/cm^2)
1	Washing machines	7.5
2	Dryers	7.5
3	Calendars	7.5
4	Hot head press	4.5
5	Steam press	4.5
6	Dry cleaning machine	4.5
7	Main kitchen	2.5
8	Health club	1.5

It was observed that at all the points, the tapping of branch lines from the main steam line is taken from top, to avoid carry over of condensate along with steam. The following components are discussed under the steam supply and distribution.

(a) Pressure reducing valves

(b) Steam traps

(c) Insulation

6.4.1 *Pressure reducing valves (PRV)*

There are three PRVs installed in the hotel complex for obtaining steam at three different pressure levels. The details of PRVs are given in **table 6.6**. The location of PRVs in the steam network are shown in **figure 6.3**.

Table 6.6. Details of PRVs

S. No	Initial pressure (kg/cm^2)	Final pressure (kg/cm^2)	Location of steam use
1	7.5	4.5	Steam press, Hot head press, Dry cleaning machine
2	7.5	2.5	Main kitchen
3	7.5	1.5	Health club

The following points can be drawn from the above table.

(i) Steam pressure required for the hot head press, steam press and dry cleaning machine is 4.5 kg/cm^2 which is obtained by reducing the steam from 7.5 kg/cm^2 in a pressure reducing (PRV-1) valve located in the laundry house.

(ii) Main kitchen requires steam at 2.5 kg/cm^2. For this purpose, steam at 7.5 kg/cm^2 is reduced in a pressure reducing valve (PRV-2).

(iii) Health club uses steam at 1.5 kg/cm^2. The required steam is generated by reducing the steam at 7.5 kg/cm^2 in a pressure reducing valve (PRV-3).

(iv) Steam at generation pressure of 7.5 kg/cm^2 is used in the washing machines, dryers and calendars.

6.4.2 *Steam traps*

Three types of steam traps are used in the steam network. The selection of steam traps for different use-areas was done on the basis of principle of operation of the trap and more importantly the type of use of the steam. The three types of traps employed in the hotel are (i) Thermodynamic, (ii) Float and (iii) Bucket type. Thermodynamic traps are used in steam coils, hot head press and dryers. Float traps are installed after the heat exchangers. Bucket traps are installed in other areas of the hotel. Weekly checks of steam traps for their operational performance are carried out by the plant personnel. The faulty traps found during the performance tests are replaced immediately to avoid loss of steam.

Steam trap testing was carried out by the energy audit team using a portable ultrasonic steam trap tester. Steam traps of all the three types were tested during the study. It was observed that all the traps tested were functioning satisfactorily.

6.4.3 *Insulation*

Glass wool is used as the insulation on steam lines and hot condensate return lines. With a view to assess the effectiveness of existing insulation, measurements of surface heat loss (radiation & convective heat losses) were taken using a portable heat flux meter, the typical values of which ranged from 170 to 220 Btu/ft^2-hr. (the ambient heat loss is 165 Btu/ft^2-hr). It is evident from the measurements that the heat loss from the insulated surfaces is not significant.

Recommendation. It was also observed that the insulation provided is either damaged or totally missing from some of the hot surfaces, such as steam lines, flanges, etc. Heat loss measurements were taken for these surfaces and the values ranged between 450-600 Btu/ft^2-hr. This shows significant amount of heat loss from the non-insulated surfaces. It should be noted that lack of proper insulation especially on saturated steam lines can lead to condensation of steam. Therefore, it is recommended to replace the damaged/missing insulation.

6.5 Condensate recovery

Condensate is recovered from two areas of the hotel complex, namely (i) laundry and (ii) main kitchen. The condensate generated in laundry house from dryers, press, calendars and dry cleaning machine, is collected and pumped into an overhead feedwater tank, by Spirax Ogden pump. The feedwater tank functions as a flash vessel. The condensate is flashed to generate steam at 1.5 kg/cm^2 and is used for hot water generation in a shell & tube heat exchanger. The condensate from the heat exchanger is finally returned to the feedwater tank. Make-up water is added to the feedwater tank. The feedwater from feedwater tank at about 95°C is pumped to the boiler.

6.6 Flash steam recovery

The total quantity of condensate generated in the hotel complex is 18 tpd. The high pressure condensate at 7.5 kg/cm^2 is flashed in a overhead feedwater tank to generate flash steam at 1.5 kg/cm^2. It is estimated that about 135 kg/hr (2.5 tpd) of flash steam is generated. The details of flash steam computation are given below.

Quantity of condensate flashed = 1246 kg/hr
Condensate pressure = 7.5 kg/cm^2
Enthalpy of condensate = 169 kcal/kg
Total heat in condensate = 211075 kcal/hr
Flash steam pressure = 1.5 kg/cm^2
Enthalpy of flash steam = 643 kcal/kg
Enthalpy of final condensate at 1.5 kg/cm^2 = 112 kcal/kg
Quantity of flash steam generated = 135 kcal/kg
Percentage flash steam generated = 10.9%

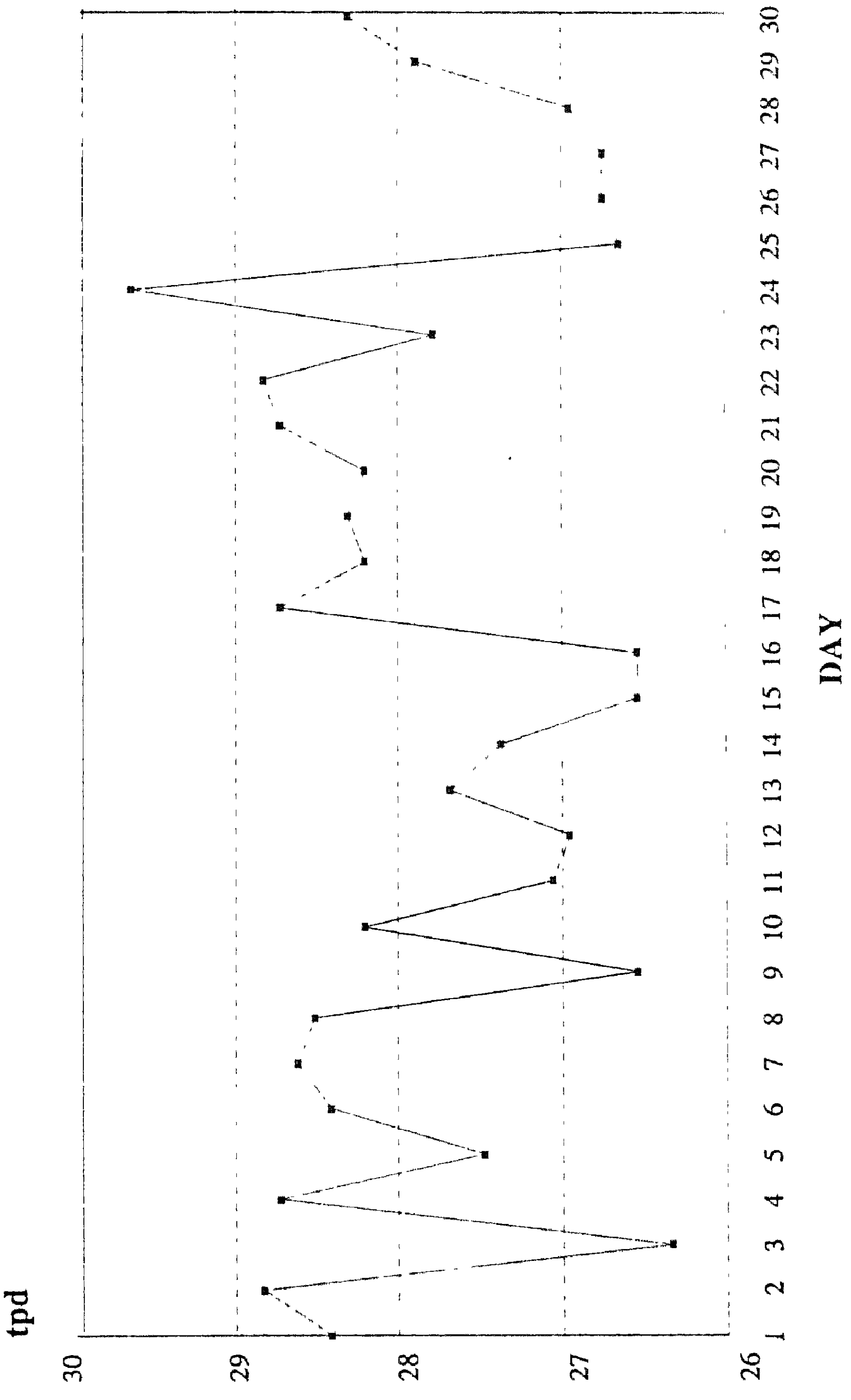
The flash steam thus generated at 1.5 kg/cm^2 is passed through a shell & tube type heat exchanger for generating hot water. The condensate from the heat exchanger is returned to the feedwater tank.

6.7 Heat exchanger

A shell and tube heat exchanger is used to generate hot water from the flash steam generated in the feedwater tank. The exchanger is a 2 pass (tube side), with steam on shell side and water on tube side. The heat exchanger tubes are made of stainless steel. The outer diameter of the tubes is 3/4". The pressure of water maintained on the tube side is 5 kg/cm^2.

Figure 6.1 DAILY STEAM DEMAND

(April 1995)



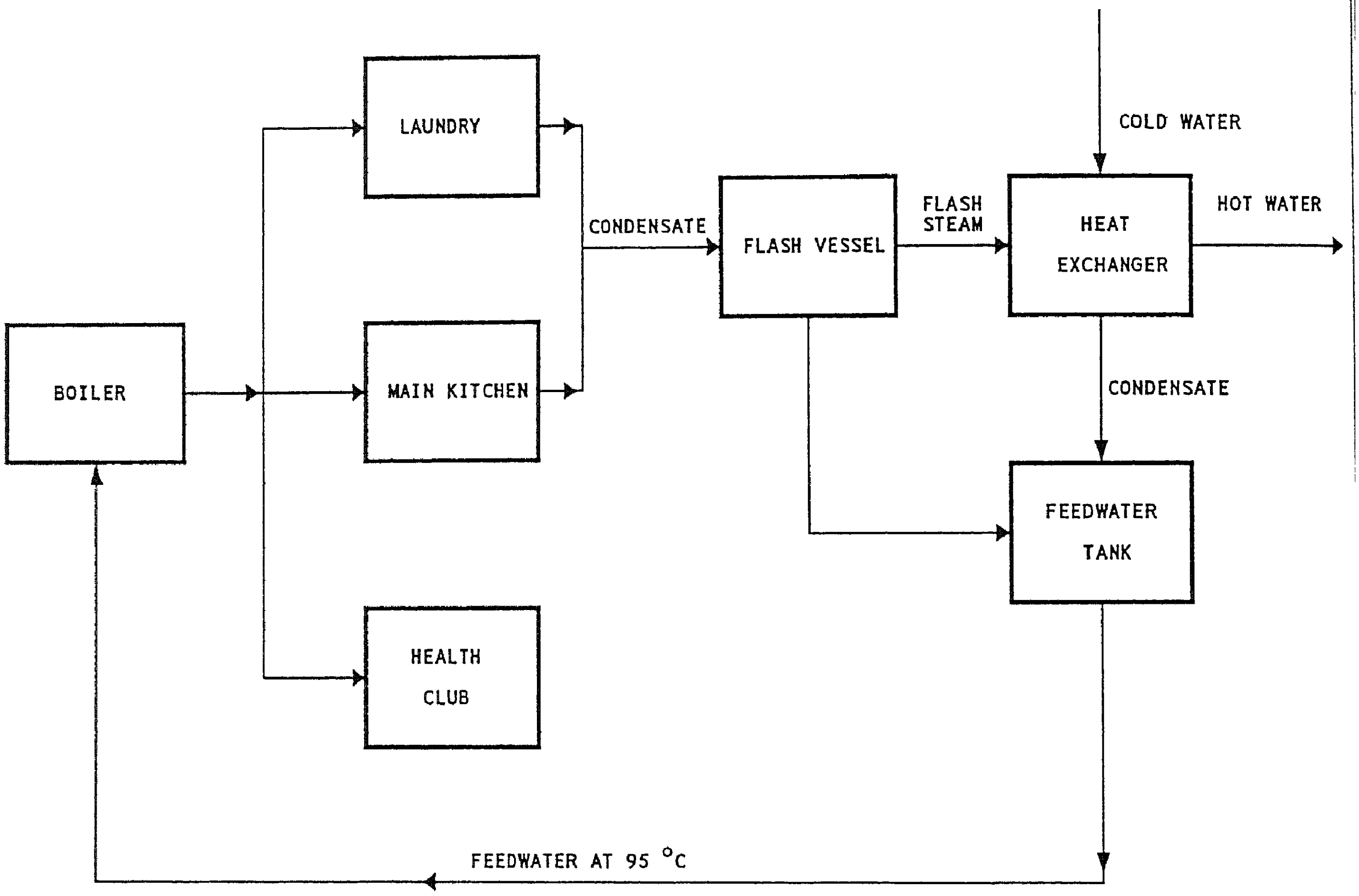


FIGURE 6.2 STEAM & CONDENSATE FLOW

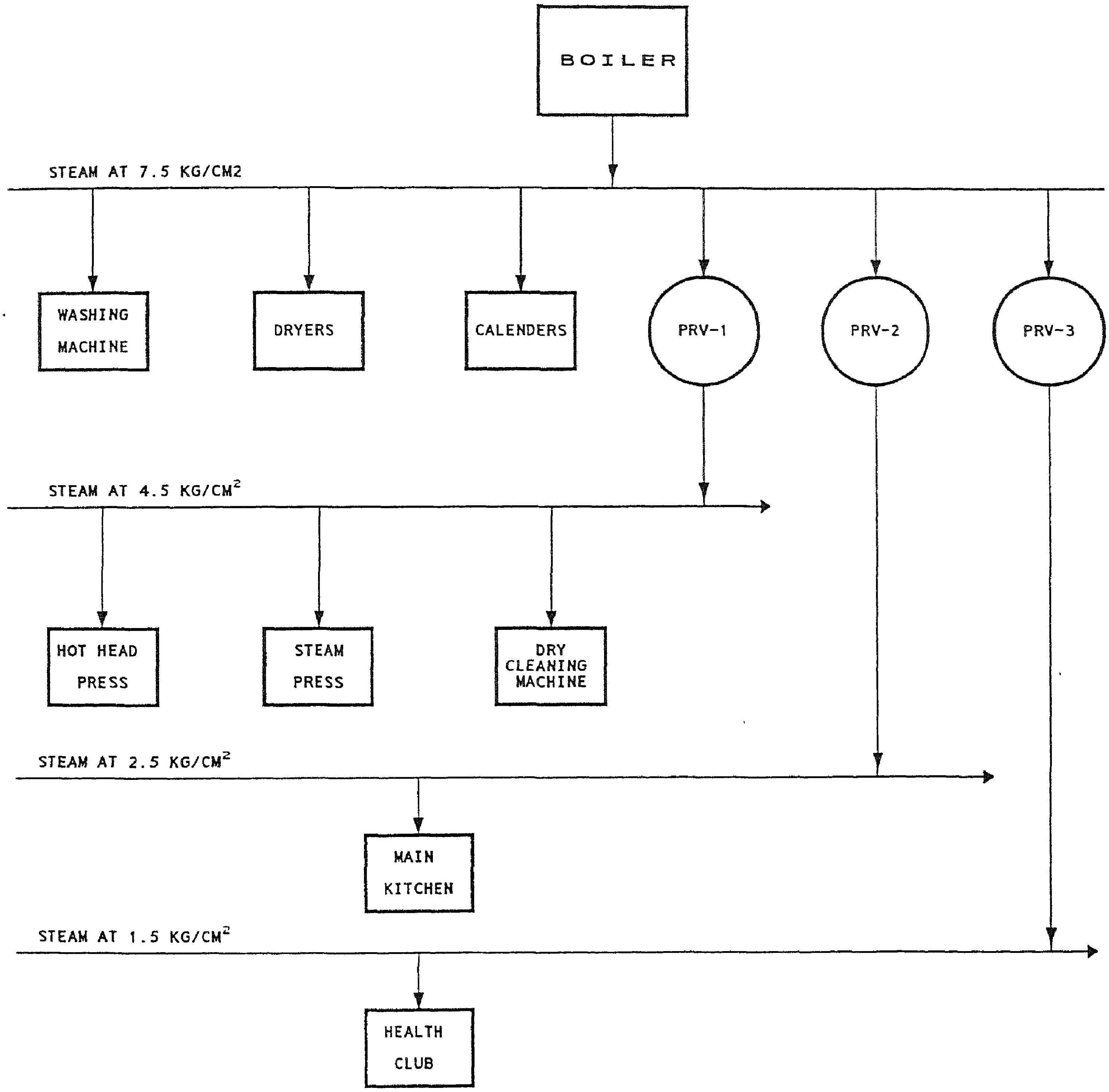


FIGURE 6.3 STEAM LINE DIAGRAM

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 FRAME      UPPER1      8.0   0.0    SOUTHSURF2 23.0    0.7        44.0
 FRAME      UPPER1      8.0   0.0    EASTSURF2  23.0    0.7        50.3
 FRAME      UPPER1      8.0   0.0    WESTSURF2  23.0    0.7        57.4
 CEILING    UPPER1      8.0   0.250  UPPER2      8.0    0.2      2106.9
 ROOF       GROUNDF     8.0   0.1    HORIZ      23.0    0.7      3504.5
 NORMAL     UPPER2      8.0   0.1    NORTHSURF2 23.0    0.7       420.3
 NORMAL     UPPER2      8.0   0.1    SOUTHSURF2 23.0    0.7       417.6
 NORMAL     UPPER2      8.0   0.1    EASTSURF2  23.0    0.7       472.8
 NORMAL     UPPER2      8.0   0.1    WESTSURF2  23.0    0.7       475.5
 FRAME      UPPER2      8.0   0.0    NORTHSURF2 23.0    0.7        17.0
 FRAME      UPPER2      8.0   0.0    SOUTHSURF2 23.0    0.7        14.0
 FRAME      UPPER2      8.0   0.0    EASTSURF2  23.0    0.7        18.0
 FRAME      UPPER2      8.0   0.0    WESTSURF2  23.0    0.7        20.2
 ROOF       UPPER2      8.0   0.250  HORIZ      23.0    0.7      3041.6


SURFACES
* EXTERIOR  COMPASS   TILT  HEIGHT  LENGTH  OVERHANG    LEFT       RIGHT
* SURFACE   AZIMUTH                            TYPE     SIDEFIN    SIDEFIN
*            [DEG]   [DEG]   [M]     [M]
*AAAAAAAAAA  XXX.X   XX.X XXXX.XX XXXX.XX AAAAAAAAAA AAAAAAAAAA AAAAAAAAAA
 EASTSURF1    90.0   90.0    6.1    68.19 <NONE>     <NONE>     <NONE>
 WESTSURF1   270.0   90.0    6.1    68.19 WESTPROJ   <NONE>     <NONE>
 NORTHSURF1    0.0   90.0    6.1    96.00 NORTHPROJ  <NONE>     <NONE>
 SOUTHSURF1  180.0   90.0    6.1    96.00 <NONE>     <NONE>     <NONE>
 EASTSURF2    90.0   90.0   19.2   100.03 <NONE>     <NONE>     <NONE>
 WESTSURF2   270.0   90.0   19.2   102.63 <NONE>     <NONE>     <NONE>
 NORTHSURF2    0.0   90.0   19.2    90.76 <NONE>     <NONE>     <NONE>
 HORIZ         0.0    0.0   80.9    80.9  <NONE>     <NONE>     <NONE>
 SOUTHSURF2  180.0   90.0   19.2    88.13 <NONE>     <NONE>     <NONE>


HVAC.TYPES
*   HVAC     HEATING  VENTING  COOLING  HEATING  VENTING  COOLING   COOLER
*   TYPE     SETPOINT SETPOINT SETPOINT CAPACITY CAPACITY CAPACITY   COIL
*              [C]      [C]      [C]      [KW]    [AC/H]    [KW]     [C]
*AAAAAAAAAA SSS.SSS  SSS.SSS  SSS.SSS  XXXX.XXX  XXX.XX  XXXX.XXX   XX.X
 CENTRAL    <NONE>   <NONE>    22.0    <ADEQ>    <ADEQ>  <ADEQ>     12.8

WALL.TYPES
*   WALL      LAYER     LAYER     LAYER     LAYER     LAYER     LAYER
*   TYPE       # 1       # 2       # 3       # 4       # 5       # 6
*AAAAAAAAAA AAAAAAAAA AAAAAAAAA AAAAAAAAA AAAAAAAAA AAAAAAAAA AAAAAAAAA
 NORMAL     CEMPLAS   BRICK     STONE     <NONE>    <NONE>    <NONE>
 FRAME      WOOD      <NONE>    <NONE>    <NONE>    <NONE>    <NONE>
 CEILING    CEMPLAS   RCC       <NONE>    <NONE>    <NONE>    <NONE>
 FLOOR      CEMPLAS   RCC       <NONE>    <NONE>    <NONE>    <NONE>
 ROOF       CEMPLAS   GLASSW    RCC       BKCOVA    <NONE>    <NONE>

MASS.TYPES
*MASS TYPE   CONDUCTIVITY   DENSITY   SPECIFIC HEAT  THICKNESS  NODES
*              [W/M-C]      [KG/CM]     [KJ/KG-C]       [M]
*AAAAAAAAAA    X.XXXX      XXXX.XXX      X.XXXX       XX.XXXX    XX.
 CEMPLAS       0.721       1762.0        0.84           0.0125    1.
 BRICK         0.811       1820.0        0.88           0.225     2.
 RCC           1.58        2288.         0.88           0.1       1.
 WOOD          0.072        480.         1.68           0.1       1.
 BKCOVA        0.798       1892.0        0.88           0.1       1.
 GLASSW        0.043         69.0        0.92           0.05      1.
 STONE         1.80        2420.0        0.88           0.02      1.

GLAZING.TYPES
* GLAZING    GLAZING   SHADING EXTINCTION  INDEX OF  THICKNESS  NUMBER
*  TYPE      U VALUE    COEF.     COEF.   REFRACTION OF LAYER     OF
*           [W/SM-C]   [FRAC]    [1/MM]     [NONE]     [MM]     LAYERS
*AAAAAAAAAA SS.SSSSS  SS.SSSSS  X.XXXX     X.XXXX    X.XXXX      XX.
 DOUBLE      3.0       1.0      0.0197     1.5260    3.0          2.
```

```
OVERHANG.TYPES
* OVERHANG   VERTICAL  HORIZONTAL
*   TYPE      OFFSET   PROJECTION
*              [M]        [M]
*AAAAAAAAAA   XX.XX      XX.XX
 WESTPROJ      0.00       3.35
 NORTHPROJ     0.00       3.35


OUTPUTS
* OUTPUT   TIME    UNITS   OUTPUT   BUILDING   OUTPUT   FORMAT?
*  TYPE   PERIOD           SEASON   ELEMENT    SECTION
*         [H/D/M]  [E/M]                                 [Y/N]
*AAAAAAAA    A       A    AAAAAAAA    XXXX.     XXXX.      A
 ZONES       H       M    YEAR        <ALL>       4.       Y
 ZONES       H       M    YEAR        <ALL>       5.       Y

SCHEDULES
*SCHEDULE SEASON   HR   VALUE     HR   VALUE     HR   VALUE     HR   VALUE
*AAAAAAAA AAAAAAAA XX. XXXX.XXX  XX. XXXX.XXX  XX. XXXX.XXX  XX. XXXX.XXX
 IGAIN1   YEAR      8.  360.0    20.  210.0    03   150.0
 IGAIN2   YEAR      8.  411.0    20.  486.0    24.  360.0    03.  180.0
 IGAIN3   YEAR     17.  180.0    23.  105.0    10.   90.0
 IGAIN4   YEAR     17.   73.0    23.   45.0    10.   35.0
 LGAIN1   YEAR      8.  285.0    20.   95.0
 LGAIN2   YEAR      8.  190.0    20.  285.0    24.  150.0    02.    50.0
 LGAIN3   YEAR     17.   57.0    10.   20.0
 LGAIN4   YEAR     17.   24.0    10.   12.0

SEASONS
* SEASON      START DATE    STOP DATE    DAY OF WEEK
*  NAME         MON DAY      MON DAY    [ALL/M-F/S-S]
*AAAAAAAA       AAA XX.      AAA XX.         AAA
 YEAR           JUN 26.      JUN 27.         ALL

STATIONS
* STATION     LAT. LONG.  ELEV.  FILENAME   DATA  UNITS  -START-  -STOP--
*  NAME      [DEG] [DEG]  [M]               TYPE  [E/M]  MON DAY  MON DAY
*AAAAAAAAAA XX.XX XXX.X XXXXX. AAAAAAAAAA  XX.     A     AAA XX.  AAA XX.
 NDELHI     28.58  77.2   216. NDELHI.WET   4.     M     JAN 01.  DEC 31.
```

BUILDING DESCRIPTION FILE FOR MAURYA TOWERS

```
RUNS
*      RUN LABEL      STATION    GROUND GROUND -START- -STOP-- SKYLINE  PAR.
*                      NAME      REFL.  TEMP.  MON DAY MON DAY PROFILE  TYPE
*                               [FRAC]   [C]   [DATE]  [DATE]
*AAAAAAAAAAAAAAAA AAAAAAAAAA S.SSSS SSS.SS AAA XX. AAA XX. AAAAAA  AAAAAA
 MAURYATOWER      NDELHI     0.200   25.6  JUN 20. JUN 30. <NONE>  <NONE>

ZONES
*    ZONE        HVAC      FLOOR  HGT  INFIL.  SOLAR  SOLAR INTERNAL  LATENT
*    NAME        TYPE      AREA         RATE  TO AIR  LOST    GAIN     GAIN
*                          [SM]   [M]  [AC/H] [FRAC] [FRAC]   [KW]     [KW]
*AAAAAAAAAA AAAAAAAAAA XXXXX.X XX.X SSS.SSS X.XXX  X.XXX SSSS.SSS SSSS.SSS
 BASEMENT   <NONE>       704.   4.1   1.     0.10   0.05  IGAIN1   LGAIN1
 GROUNDF    CENTRAL      704.   6.7   2.     0.10   0.05  IGAIN2   LGAIN2
 UPPER      CENTRAL      704.   28    2.     0.10   0.05  IGAIN3   LGAIN3

WINDOWS
* INTERIOR   EXTERIOR   GLAZING      HEIGHT  LENGTH  ---LOCATION----
*   ZONE     SURFACE     TYPE                         HORZ.   VERT.
*                                      [M]     [M]     [M]     [M]
*AAAAAAAAAA AAAAAAAAAA AAAAAAAAAA   XXXX.XX XXXX.XX XXXX.XX XXXX.XX
 GROUNDF    NORTHSURF1 DOUBLE          3.29   19.43    5.38    1.71
 UPPER      WESTSURF2  DOUBLE         17.19    1.9    14.14    5.4
 UPPER      EASTSURF2  DOUBLE         17.19    1.9    14.14    5.4
 UPPER       NORTHSURF2 DOUBLE           19.98    11.06    10.59     4.01
 UPPER       SOUTHSURF2 DOUBLE           19.98    11.06    10.59     4.01

WALLS
*   WALL      --FRONT/INTERIOR SIDE--   --BACK/EXTERIOR SIDE---    WALL
*   TYPE        ZONE     SURF   SOLAR   ZONE OR    SURF  SOLAR     AREA
*               NAME     COEF   COEF.   SURFACE,   COEF  COEF.
*                        [W/C  [FRAC]   AMBIENT,   [W/C  [FRAC]    [SM]
*                        -SM]           GROUND     -SM]
*AAAAAAAAAA AAAAAAAAAA XX.XXX X.XXXX AAAAAAAAAA XX.XXX X.XXXX  XXXXX.X
 NORMAL     BASEMENT    8.0   0.3    GROUND      1.0   1.0       511.9
 FLOOR      BASEMENT    8.0   0.3    GROUND      1.0   1.0       703.7
 CEILING    BASEMENT    8.0   0.25   GROUNDF     8.0   0.1       703.7
 NORMAL     GROUNDF     8.0   0.1    EASTSURF1  23.0   0.7       202.2
 NORMAL     GROUNDF     8.0   0.1    WESTSURF1  23.0   0.7       202.2
 NORMAL     GROUNDF     8.0   0.1    NORTHSURF1 23.0   0.7       140.8
 NORMAL     GROUNDF     8.0   0.1    SOUTHSURF1 23.0   0.7       216.0
 CEILING    GROUNDF     8.0   0.25   UPPER       8.0   0.085     703.7
 FRAME      GROUNDF     8.0   0.1    NORTHSURF1 23.0   0.7        11.3
 NORMAL     UPPER       8.0   0.085  EASTSURF2  23.0   0.7       104.2
 NORMAL     UPPER       8.0   0.085  WESTSURF2  23.0   0.7       104.2
 NORMAL     UPPER       8.0   0.085  NORTHSURF2 23.0   0.7       642.8
 NORMAL     UPPER       8.0   0.085  SOUTHSURF2 23.0   0.7       642.8
 ROOF       UPPER       8.0   0.085  HORIZ      23.0   0.7       703.7
 FRAME      UPPER       8.0   0.085  EASTSURF2  23.0   0.7         8.2
 FRAME      UPPER       8.0   0.085  WESTSURF2  23.0   0.7         8.2
 FRAME      UPPER       8.0   0.085  NORTHSURF2 23.0   0.7        38.9
 FRAME      UPPER       8.0   0.085  SOUTHSURF2 23.0   0.7        38.9

SURFACES
* EXTERIOR  COMPASS  TILT  HEIGHT  LENGTH  OVERHANG    LEFT       RIGHT
2* SURFACE   AZIMUTH                          TYPE     SIDEFIN    SIDEFIN
*            [DEG]  [DEG]    [M]     [M]
*AAAAAAAAAA  XXX.X    XX.X XXXX.XX XXXX.XX AAAAAAAAAA AAAAAAAAAA AAAAAAAAAA
 EASTSURF1    90.0   90.0     6.7    30.18 <NONE>     <NONE>     <NONE>
 WESTSURF1   270.0   90.0     6.7    30.18 WESTPROJ   <NONE>     <NONE>
 NORTHSURF1    0.0   90.0     6.7    32.24 <NONE>     <NONE>     <NONE>
 SOUTHSURF1  180.0   90.0     6.7    32.24 <NONE>     <NONE>     <NONE>
 EASTSURF2    90.0   90.0    28.0    30.18 <NONE>     <NONE>     <NONE>
 WESTSURF2   270.0   90.0    28.0    30.18 <NONE>     <NONE>     <NONE>
 NORTHSURF2    0.0   90.0    28.0    32.24 <NONE>     <NONE>     <NONE>
 HORIZ         0.0    0.0    26.5    26.5  <NONE>     <NONE>     <NONE>
 SOUTHSURF2  180.0   90.0    28.0    32.24 <NONE>     <NONE>     <NONE>

HVAC.TYPES
*   HVAC    HEATING  VENTING  COOLING  HEATING  VENTING  COOLING   COOLER
*   TYPE    SETPOINT SETPOINT SETPOINT CAPACITY CAPACITY CAPACITY   COIL
*             [C]      [C]      [C]      [KW]    [AC/H]    [KW]      [C]
 CENTRAL    <NONE>   <NONE>    22.0    <ADEQ>   <ADEQ>   <ADEQ>     12.8

WALL.TYPES
*   WALL      LAYER      LAYER      LAYER      LAYER      LAYER      LAYER
*   TYPE       # 1        # 2        # 3        # 4        # 5        # 6
*AAAAAAAAAA AAAAAAAAA  AAAAAAAAA  AAAAAAAAA  AAAAAAAAA  AAAAAAAAA  AAAAAAAAA
 NORMAL     CEMPLAS    BRICK      STONE      <NONE>     <NONE>     <NONE>
 FRAME      WOOD       <NONE>     <NONE>     <NONE>     <NONE>     <NONE>
 CEILING    CEMPLAS    RCC        <NONE>     <NONE>     <NONE>     <NONE>
 FLOOR      CEMPLAS    RCC        <NONE>     <NONE>     <NONE>     <NONE>
 ROOF       CEMPLAS    GLASSW     RCC        BKCOVA     <NONE>     <NONE>

MASS.TYPES
*MASS TYPE   CONDUCTIVITY   DENSITY    SPECIFIC HEAT  THICKNESS   NODES
*              [W/M-C]      [KG/CM]     [KJ/KG-C]       [M]
*AAAAAAAAAA    X.XXXX      XXXX.XXX       X.XXXX       XX.XXXX     XX.
 CEMPLAS       0.721       1762.0         0.84          0.0125      1.
 BRICK         0.811       1820.0         0.88          0.225       2.
 RCC           1.58        2288.          0.88          0.1         1.
 WOOD          0.072        480.          1.68          0.1         1.
 BKCOVA        0.798       1892.0         0.88          0.1         1.
 GLASSW         0.043        69.0         0.92          0.05       1.
 STONE          1.80       2420.0         0.88          0.02       1.

GLAZING.TYPES
* GLAZING    GLAZING   SHADING EXTINCTION   INDEX OF  THICKNESS  NUMBER
*  TYPE      U VALUE    COEF.     COEF.    REFRACTION OF LAYER     OF
*            [W/SM-C]   [FRAC]    [1/MM]     [NONE]     [MM]     LAYERS
*AAAAAAAAAA  SS.SSSSS  SS.SSSSS  X.XXXX      X.XXXX    X.XXXX      XX.
 DOUBLE       3.0       1.0      0.0197      1.5260    3.0          2.

OVERHANG.TYPES
* OVERHANG   VERTICAL  HORIZONTAL
*   TYPE      OFFSET   PROJECTION
*              [M]         [M]
 WESTPROJ      0.00       3.35

OUTPUTS
* OUTPUT   TIME   UNITS   OUTPUT   BUILDING    OUTPUT   FORMAT?
*  TYPE   PERIOD          SEASON   ELEMENT     SECTION
*         [H/D/M] [E/M]                                  [Y/N]
*AAAAAAAA    A       A   AAAAAAAA     XXXX.      XXXX.      A
 ZONES       H       M   YEAR         <ALL>         4.      Y
 ZONES       H       M   YEAR         <ALL>         5.      Y

SCHEDULES
*SCHEDULE  SEASON  HR   VALUE    HR   VALUE     HR   VALUE    HR   VALUE
*AAAAAAAA AAAAAAAA XX. XXXX.XXX  XX. XXXX.XXX   XX. XXXX.XXX  XX. XXXX.XXX
 IGAIN1   YEAR      8.    6.75   20.     3.
 IGAIN2   YEAR      8.   16.9    20.    10.
 IGAIN3   YEAR     17.   86.0    23.    10.      10.  15.0
 LGAIN1   YEAR      8.    2.25   20.     0.
 LGAIN2   YEAR      8.    1.80   20.     0.5
 LGAIN3   YEAR     17.   11.25   20.     5.

SEASONS
* SEASON     START DATE    STOP DATE    DAY OF WEEK
*  NAME        MON DAY      MON DAY    [ALL/M-F/S-S]
*AAAAAAAA      AAA XX.      AAA XX.          AAA
 YEAR          JUN 26.      JUN 27.          ALL

STATIONS
* STATION    LAT. LONG.  ELEV.  FILENAME  DATA   UNITS  -START-  -STOP--
*  NAME     [DEG] [DEG]  [M]              TYPE   [E/M]  MON DAY  MON DAY
 NDELHI     28.58  77.2   216. NDELHI.WET   4.     M    JAN 01.  DEC 31.
```

Annexure 1.2

Energy Efficient Motors

Energy-efficient motors are such designed that their full load efficiency is higher by 4 per cent of that of standard motors and remain as high at low loads. The power factor of such motors are also slightly higher than the standard motors at all loads. Presently Crompton Greaves and Siemens are manufacturing these motors in the country. Use of these motors therefore, is justified especially in the lower ranges of motor rating, where efficiency improvements are significantly higher than for motors higher rating.

The advantages of energy-efficient motors are:

- Higher electric power saving
- Low life-cycle cost
- Improved ability to perform under adverse conditions such as abnormal voltage
- Lower operating temperatures
- Lower noise level
- Ability to accelerate higher-inertia loads
- Higher operating efficiencies at all loads

In certain applications and duty cycles, energy efficient motors cannot be justified on the basis of energy saved, for example:

- **Intermittent duty or special torque applications**
- Hoists and cranes
- Traction drives
- Punch presses
- Machine tools
- Oil field pumps
- Fire pumps
- Centrifugals
- **Types of loads**
- Multispeed
- Frequent starts & stops
- Very high inertia-loads
- Low-speed motors (below 720 rpm)

Annexure 1.3

Heat Balance: Boiler-1

Heat input

Number of baskets of coal consumed per hour =
Average weight of coal per basket = kg
Coal consumption = kg/hr
Heat input = kcal/hr

Heat output (heat losses)

(i) Flue gas loss

a. Dry flue gas loss
Oxygen content in flue gas = 8.9%
Excess air level = 69%
Flue gas temperature = 230°C
Ambient temperature = 30°C
Amount of flue gas generated = 2798 kg/hr
Sensible heat in dry flue gas = 136650 kcal/hr
Dry flue gas loss = 10.9%

b. Heat loss due to hydrogen in fuel
Hydrogen content of fuel = 0.06 kmol/kg fuel
Total hydrogen in fuel = 7.1 kmol/hr
Heat loss due to hydrogen in fuel = 80961 kcal/hr
= 6.5 %

c. Heat loss due to moisture in fuel
Moisture content of fuel = 0.000 kmol/kg fuel
Total moisture in fuel = 0.033 kmol/hr
Heat loss due to moisture in fuel = 401 kcal/hr
= 0.0 %

d. Heat loss due to moisture in air

Dry bulb temperature = 30°C

Wet bulb temperature = 27°C

Molal humidity = 0.029 kmol/kmol dry air

Total moisture in air = 2.81 kmol/hr

Heat loss due to moisture in air = 4615 kcal/hr

= 0.4 %

Flue gas loss (a + b + c + d) = 17.8 %

(ii) Heat loss due to CO in flue gas

CO content in flue gas = 185 ppm

Carbon converted to CO = 0.0001 kmol/kg fuel

Total carbon in CO = 0.21 kg/hr

Heat loss due to CO formation = 1177 kcal/hr

Percentage heat loss due to CO in flue gas = 0.1 %

(iii) Heat loss due to blowdown

Present blowdown rate = 10 %

Quantity of blowdown water = 75 kg/hr

Enthalpy of blowdown water = 119 kcal/kg

Heat loss due to blowdown = 8912 kcal/hr

Percentage of heat loss due to blowdown = 0.7 %

(v) Structural heat loss

Ambient heat loss = 162 Btu/ft^2-hr

Total heat loss from the boiler surfaces = 6109 kcal/hr

Structural heat loss = 0.5 %

Table 1. Structural heat loss measurements

Location	*Area (m^2)*	*Measured loss (Btu/ft^2-hr)*	*Net heat loss (kcal/hr)*
Zone-1	1.2	232	231
Zone-2	2.9	215	414
Zone-3	4.6	301	1717
Zone-4	2.8	201	294
Zone-5	0.1	531	111
Zone-6	0.4	641	573
Zone-7	2.8	452	2212

Table 2. Summary of the heat balance

Type of loss	Percentage
Flue gas loss	17.8
Heat loss due to CO in flue gas	0.1
Structural heat loss	0.5
Heat loss due to blowdown	0.7
Total heat loss	*19.1*
Thermal efficiency of the boiler	80.9